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**JOHN F. KENNEDY
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MANUAL

Ground Support Equipment

INTRODUCTION

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This manual sets forth the requirements, procedures, and practices for the preparation, release, maintenance, control, and utilization of engineering drawings by engineering and drafting personnel. Certain design material has been included as guidelines and aids for the design of Ground Support Equipment.

The engineering drawings prepared by or for the procuring activity shall be "Government Design Activity Drawings," as defined in Section I, and the adherence to the contents herein is essential to the standardization and uniform interpretation of these drawings. The class of drawings to be prepared by contractors and the extent of adherence to this manual shall be as directed by contract or order.

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DRAWING CLASSES

1.1 GENERAL

All drawings shall be "design activity drawings." A "design activity" is an organizational unit having responsibility for the design, preparation, and maintenance of engineering drawings for a given item of supply.

1.2 CLASSES OF DRAWINGS

The "design activity" drawings described in Paragraph 1.1 shall be classified as follows:

1.2.1 GOVERNMENT DESIGN ACTIVITY DRAWINGS

"Government design activity drawings" are drawings furnished or prepared as Government agency drawings by a Government design activity or a contractor and for which the Government agency retains or assigns responsibility for the preparation and/or maintenance. These drawings are assigned Government identification code and Government drawing numbers from a block of numbers issued by a Government activity.

1.2.2 CONTRACTOR DESIGN ACTIVITY DRAWINGS

"Contractor design activity drawings" are drawings which are furnished or prepared as contractor design activity drawings by or for a contractor design activity and for which the contractor design activity has responsibility for the preparation and maintenance.

These drawings shall be identified by the identification code and drawing numbers assigned by the design activity contractor.



TYPES AND DEFINITIONS OF ENGINEERING DRAWINGS

2.1 GENERAL

■ This section defines basic types of drawings prepared by or for KSC to disclose physical and functional engineering information by means of pictorial or textual presentations.

2.2 ARRANGEMENT DRAWING

An arrangement drawing depicts in any projection or perspective, with or without controlling dimensions, the relationship of major units of the item depicted.

2.2.1 REQUIREMENTS

An arrangement drawing shall show sufficient views of the item so that a general understanding is conveyed of the configuration and location of major units. Overall, locating, and other general dimensions necessary to define the configuration may be shown. Major units shall be identified.

2.3 ASSEMBLY DRAWING

An assembly drawing depicts the assembled relationship of two or more parts, or a combination of parts and subassemblies or a group of assemblies required to form an assembly of higher order.

2.3.1 REQUIREMENTS

An assembly drawing shall contain sufficient views to show the relationship between each subassembly and part comprising the assembly depicted. Subassemblies and parts shall be called out in the field of the drawing by find (item) numbers cross-referenced to the identifying numbers in a parts list. When information regarding the assembled relationship and identification of parts is shown on subassemblies, it should not be repeated on the assembly drawing of next higher order, only the identifying number of each such subassembly, its configuration and location being shown; however, when the intent and purpose of the assembly drawing will not be adversely affected, outline and installation information may be shown. Assembly drawings shall contain references to pertinent installation drawings, wiring and schematic diagrams, etc., as applicable. The division of an item into subassemblies should be in accordance with practical assembly and disassembly procedures.

2.3.1.1 Electrical Items

Electrical items shall be shown and identified on assembly drawings; however, small electrical items mounted by means of wire connections may be shown and identified either on the assembly drawing or on the pertinent wiring diagram.



TYPES AND DEFINITIONS OF ENGINEERING DRAWINGS

2.3.1.2 Attaching Parts

Attaching parts (bolts, nuts, washers, etc.) required to mount and retain assemblies shall be called out on the drawing by find (item) numbers showing the item on which the attachment takes place.

2.4 BOOK-FORM DRAWING

A book-form drawing is an assemblage of several sheets of data under a single identifying drawing number and title, disclosing by means of pictorial delineations or technical tabulations or combinations thereof, the engineering requirements of an item, a family of items, or a system. A book-form drawing is used for special-purpose application in which it is necessary to provide a document consisting of numerous small sheets, suitable for binding into book form.

2.4.1 REQUIREMENTS

A book-form drawing shall be prepared on A-size drawing formats; however, other standard size formats may be used provided the final original document size sheets are reduced to 11-inch height and can be folded to 8.5-inch width, with resultant legibility maintained. Book-form drawings shall not be prepared to circumvent the requirements for furnishing the individual types of drawings required for the delineation of an item or system.

2.5 CONTROL DRAWING

A control drawing depicts an existing commercial item, other than government standard, specifying engineering requirements to the extent necessary to ensure identification and procurement of the item delineated, without necessarily disclosing details of design.

2.5.1 REQUIREMENTS

A control drawing shall disclose, as applicable, configuration, dimensions of envelope (expressed as limits or as maxima), mounting and mating dimensional limits, and all other interface dimensional characteristics affecting interchangeability of the item. In addition, performance, reliability, maintainability, environmental and other functional interchangeability requirements, necessary to meet design and acceptance test requirements, shall also be specified, either on the drawing or in a document invoked thereon. If an electrical or electronic (or other engineering) circuit is involved, a schematic, connection, or other appropriate diagram shall be included on the drawing or in a referenced document, thereby providing sufficient information for making external connections.



TYPES AND DEFINITIONS OF ENGINEERING DRAWINGS

2.5.1.1 Specification Control Drawing

A specification control drawing discloses configuration, design and test requirements for the item, other than Government standard items, designed and manufactured by vendors. Vendor's part numbers, names, and addresses are included on the drawing. When the specification control drawing number is used as the identifying number on an assembly drawing, list, etc., a note shall be placed on the assembly drawing or list to the effect that: "FOR PROCUREMENT OR PART NUMBER SEE SPECIFICATION CONTROL DRAWING." A specification control drawing shall be identified by the words "SPECIFICATION CONTROL DRAWING" adjacent to the title block.

2.5.1.2 Altered-Part Drawing

An altered-part drawing depicts an item produced by a design manufacturer under his part or catalog number or a Government standard item that has been modified for use by the using activity. The drawing shall be made only when the existing vendor or Government item cannot be used as is and then only after the vendor has rejected a request to make the alterations and assign a new part identification for the item as altered. The drawing shall contain sufficient data to allow procurement of the original item from the same or other source. All alteration information shall be clearly shown in detail and marked with an asterisk (*) to distinguish this information from any other that may be supplied; a note as follows is required on the drawing: "All dimensions, requirements, etc., marked by an asterisk (*), are alterations of the items as supplied under the vendor's identification number." The drawing is identified by the using activity's name and number and shall show the vendor's name, address, and part number. However, when identifying the part, the vendor's identification shall be removed and re-identified with a number which shall be, or shall include, the drawing number of the altered-part drawing. An altered-part drawing shall be identified by the words "ALTERED-PART DRAWING" immediately above the title block.



TYPES AND DEFINITIONS OF ENGINEERING DRAWINGS

2.6 DETAIL DRAWING

A detail drawing consists of sufficient delineation or description, with necessary dimensioning and supporting information required to define the part(s).

2.6.1 REQUIREMENTS

A detail drawing shall define all features of the part(s) depicted, including, as applicable, configuration, dimensions, tolerances, materials, mandatory processes, surface finish, protective coating, symbols, etc. Documents required to supplement the drawing in stating end-product requirements for the part shall be prescribed by notes or tables on the drawing.

2.6.1.1 Monodetail Drawing

A detail drawing that delineates a single part.

2.6.1.2 Multidetail Drawing

A detail drawing that delineates two or more parts.

2.7 DETAIL ASSEMBLY DRAWING

A detail assembly drawing depicts an assembly on which one or more parts are detailed within the assembly view or auxilliary views, in lieu of preparing separate detail drawings.

2.7.1 REQUIREMENTS

A detail assembly shall identify or define all items necessary to complete the assembly and define their assembled relationship. Other requirements shall be those specified for a monodetail drawing (Paragraph 2.6.1) and an assembly drawing (Paragraph 2.3.1).

2.8 DIAGRAM DRAWINGS

A diagram drawing delineates features and relationship of items forming an assembly or system by means of symbols and lines. A diagram drawing is a graphic explanation of

TYPES AND DEFINITIONS OF ENGINEERING DRAWINGS

2.8 (Contd)

the manner by which an installation, assembly, or system (e.g., mechanical, electrical, electronic, hydraulic, pneumatic) performs its intended function.

2.8.1 REQUIREMENTS- ELECTRICAL AND ELECTRONIC DIAGRAMS

Electrical and electronic diagrams defined below shall meet the requirements prescribed by KSC-STD-152-1.

2.8.1.1 Advanced Schematic

An advanced schematic diagram shows, by means of graphical symbols, the detailed electrical connections and functions of component items used within a specific circuit or system of circuits and facilitates the tracing of the circuit(s) from item to item in the sequence of their respective functions with no attempt to indicate physical size, shape, or location.

2.8.1.2 Elementary Schematic

An elementary schematic diagram is basically the same as an advanced schematic but omits much of the detailed wire connections of the component items.

2.8.1.3 Wiring or Connection

A wiring or connection diagram shows pictorially and/or by list the connections of an installation or its component items. It may cover internal or external connections, or both, contain details needed to make and trace connections, and will usually show general physical arrangement of the component items.

2.8.1.4 Interconnection

An interconnection diagram is a form of wiring or connection diagram which shows only external connections between unit assemblies or equipments. Internal connections are usually omitted, but may be included where necessary for clarity of function.

2.8.2 MECHANICAL SCHEMATIC

A mechanical schematic diagram illustrates the operational sequence or arrangement of a mechanical device.



TYPES AND DEFINITIONS OF ENGINEERING DRAWINGS

2.8.2.1 Requirements

Sufficient detail shall be shown to explain the operational sequence or arrangement. The schematic may be isometric, semi-isometric, in perspective, or drawn as if all features were in a single plane. Nomenclature, symbols, part identifying numbers, and dimensions should be shown as required.

2.8.3 PIPING DIAGRAM

A piping (hydraulic, pneumatic or fluid) diagram depicts the interconnection of components by piping, tubing or hose, and when desired, sequential flow of fluids in the system.

2.8.3.1 Requirements

Sufficient detail shall be shown to explain the arrangement of the piping, valves, etc., or operational sequence. Symbolic line representation may be used to distinguish functions of various parts. When the objective is to show arrangement, the following characteristics may be shown: routing of fluids, physical locations and arrangement of components, pipe diameters, types and sizes of fittings, flow, pressure, volume, etc..

2.8.4 BLOCK DIAGRAM

A block diagram utilizes block outlines to designate units or functional groups which are connected with lines to indicate relationships.

2.8.4.1 Requirements

A block diagram is presented in as simple a form as possible. Blocks shall represent units or functional units, etc. Lines connecting blocks shall indicate relationships, direction of flow of the system, sequence of operation, etc. Arrowheads shall be used on lines to indicate direction, which is generally from left to right or from top to bottom. All necessary identifications and explanatory notes shall be entered on the drawing. Identifying nomenclature shall be included within the block. Dashed-line blocks may be used to indicate optional items or testing functions.

2.9 ENVELOPE DRAWING

An envelope drawing discloses configuration, performance, and test requirements to the extent necessary to enable development of design details of a new item.

TYPES AND DEFINITIONS OF ENGINEERING DRAWINGS

2.9.1 REQUIREMENTS

An envelope drawing depicts configuration, mounting and mating dimensions, other necessary dimensions, performance, installation, reliability and interchangeability characteristics, and test requirements to the extent necessary to develop design details of the item delineated. If an electrical, electronic, or other engineering circuit is involved, a schematic, connection, or other appropriate diagram shall be included, or referenced, in order to provide information for making external connections.

2.10 ERECTION DRAWING

An erection drawing shows procedures and operation sequence for erection or assembly of individual items or assemblies of items.

2.10.1 REQUIREMENTS

An erection drawing shall show the location of each part in the structure, identification markings, types of fastenings required, approximate weight of heavy structural members, controlling dimensions, and any other information which will contribute to erection of the structure.

2.11 FACILITIES DRAWINGS

Facilities drawings define the design of buildings, structures, sites, or related construction individually or in groups.

2.11.1 REQUIREMENTS

The general requirements and practices for facilities drawings shall be per NPC 500-2 Facilities Drafting Manual. The following list of drawings is not intended to be all inclusive, but to give a sampling of those included as facilities type drawings.

Vicinity plan
Topographic
Master plan
Plot plan
Floor plan
Elevations

Flow diagrams
Facilities Equipment
Heating Ventilation and
Air Conditioning
Construction
Structural

TYPES AND DEFINITIONS OF ENGINEERING DRAWINGS

2.12 INTERFACE CONTROL DRAWINGS

An interface control drawing defines a point or area where a relationship exists between two or more parts, systems, programs, or procedures wherein physical and/or functional compatibility is required. These drawings are used as design control documents, establishing, controlling and maintaining compatibility between interfaces, and communicating design decisions and changes to participating activities.

2.12.1 REQUIREMENTS

Interface control drawings shall meet the requirements specified in Section 18.

2.13 INSTALLATION DRAWING

An installation drawing shows general configurations, attaching hardware, and information to locate, position, and install an item relative to its supporting structure or to associated items.

2.13.1 REQUIREMENTS

An installation drawing shall include the following, as applicable:

- a. Interface mounting and mating information, such as attaching hardware and its dimensions of location.
- b. Interface pipe and cable attachments required for the installation and cofunctioning of the item to be installed with related items.
- c. Information necessary for preparation of foundation plans, including mounting plate details, drilling plans and shock mounting, and buffer details.
- d. Location, size and arrangement of ducts.
- e. Weight of unit.
- f. Location, type and dimensions of cable entrances, terminal tubes, and electrical connectors.
- g. Interconnecting and cabling data.



TYPES AND DEFINITIONS OF ENGINEERING DRAWINGS

2.13.1 (Contd)

- h. When not disclosed on an installation control drawing (para. 2.25), overall and principal dimensions in sufficient detail to establish the limits of space in all directions required for installation, operation, and servicing. The amount of clearance required to permit the opening of doors or the removal of plug-in units shall be included. Clearance for travel or rotation of any moving parts shall be shown, including the centers of rotation, angles of train in azimuth, elevation and depression, and radii from each pivot to the end of each rotating element involved in clearance determination.

2.14 LISTS**2.14.1 DATA LIST**

A data list is a tabulation of engineering drawings, associated parts lists, and documents referenced thereon, and next lower subordinate data lists pertaining to the item to which the list applies.

2.14.1.1 Requirements

A data list shall tabulate design activity data lists (if any) at the next lower assembly level and vendor(s) data list(s) (if any) at the next lower assembly level, in addition to the following documents that are not tabulated on such listed subordinate data lists: design activity drawings, parts lists, vendor detail or assembly drawings not otherwise listed on data lists, and referenced documents applicable to the item(s) to which the list applies. The documents tabulated shall include specifications and standards referenced, either in the field of drawings or on the parts lists.

2.14.2 INDEX LIST

An index list is a tabulation of lists applicable to the end item, or to the complete system, to which the list applies.

2.14.2.1 Requirements

An index list shall tabulate either all data lists applicable to an end item, or all index lists of the subordinate end items for a complete system. An index list is not necessary if there is only one data list for the complete end item or if the top data list includes all applicable data lists.

TYPES AND DEFINITIONS OF ENGINEERING DRAWINGS

2.14.3 PARTS LIST

The parts list is a tabulation of items required to fabricate or assemble the end item(s) to which it applies.

2.14.3.1 Requirements

A parts list shall tabulate all parts, assemblies, and materials applicable to the item on the drawing to which the list applies.

2.14.4 RUNNING LIST

A running list is a drawing consisting of tabular data and instructions required to establish wiring connections between units of an equipment, or between equipment, sets or assemblies of a system.

2.14.4.1 Requirements

A running list used in conjunction with a connection diagram, wiring harness or an assembly drawing used as a connection diagram, provides detailed wiring information in convenient list form. A running list shall be identified by its own drawing number and be referenced on its associated drawing.

2.14.5 PATCH LIST (Patch Board Wire Routing List)

A patch list is a drawing consisting of tabular data and instructions to establish wiring connections at a central switching point which provides interfacing and flexibility of change for circuitry between units of equipment and associated systems.

2.14.5.1 Requirements

A patch list used in conjunction with a patch board and patch rack provides detailed wiring information in convenient list form. A patch list shall be identified by its own drawing number and be referenced on its associated drawing.

2.15 MATCHED-PARTS DRAWING

A matched-parts drawing depicts parts which are machine matched or otherwise mated, and for which assembly or replacement as a matched set or pair is essential.

TYPES AND DEFINITIONS OF ENGINEERING DRAWINGS

2.15.1 REQUIREMENTS

This type of drawing is used for parts which must be assembled, ordered, or stocked as a set or pair for proper functioning of the equipment such as: gears, springs, electronic parts, bearing housings, etc.

A single matched-parts drawing shall designate each matched set or pair and shall state the operating or mating characteristics that are the primary reasons for the use of matched parts. The individual matched parts may be detailed on the matched-parts drawing, if practical, in lieu of separate detail drawings; however, a single part number, which shall be the number of the matched-parts drawing or shall include the number of the matched-parts drawing, shall be assigned to each matched part. The drawing shall require identification marking on each matched part. A note such as "Furnish only as a matched set" shall be stated on the drawing.

2.16 MODIFICATION DRAWING

A modification drawing is a drawing that shows how a completed item is to be altered for a specific application.

2.16.1 REQUIREMENTS

Modification drawings are used to describe the modification to be made to a completed item, usually after acceptance and delivery, but never without approval. The modification drawing may be used in the preparation of, or become a part of, the instructions included in the modification kit, but will always serve as an engineering record of alterations made to equipment in the field. The original records of the equipment as shipped shall include records of equipment modified.

The modification drawing shall contain or reference all information necessary to accomplish the modification. For example it shall:

- a. Identify the item to be modified and indicate its new identity, when required, after modification.
- b. Show the item in sufficient detail to describe how the modification is to be accomplished, with before and after modification delineation or description.
- c. List and identify all items to be removed and all items to be altered or added.

TYPES AND DEFINITIONS OF ENGINEERING DRAWINGS

2.17 MODIFICATION KIT DRAWING

A modification kit drawing is a drawing listing all parts, materials, and instructions that are required to make up a complete kit or package for use in retrofitting or modifying an item.

2.17.1 REQUIREMENTS

Whereas the modification drawing is used to describe the modification, the kit drawing is used to list or group together everything needed for the modification, such as all parts, instructions, other kits, tools, identification plates, etc., including item identification, nomenclature, and quantity required.

2.18 MULTISHEET DRAWING

A multisheet drawing consists of two or more sheets applicable to the same item. A multisheet drawing is not a type of drawing in the sense of a detail or assembly drawing; rather, the term "multisheet drawing" describes the use of several sheets in presenting all information applicable to a single drawing of any one of several types, as opposed to the use of a single roll or flat sheet.

2.18.1 REQUIREMENTS

All requirements to the particular type of drawing being prepared shall apply. All sheets will be the same size format, and the title and drawing number shall be the same for all sheets.

2.19 PROPOSAL AND LAYOUT DRAWINGS

Proposal and layout drawings are prepared for investigation and study of the design of an item, and to convey its features for approval prior to the preparation and release of working drawings for the purpose of producing a contract item.

2.19.1 REQUIREMENTS

Layout drawings shall present the investigation and study of the design while the proposal drawing will convey its features to the customer. The drawings shall be identified by a number, assigned in the same manner as for production drawings, meeting the requirements specified in Section 11.

2.20 SELECTED PART DRAWING

A selected-part drawing depicts an item produced by a design manufacturer under his part or catalog number, or a Government standard item, that has been selected for fit, tolerance, performance, etc., for use by the contractor or using design activity.

TYPES AND DEFINITIONS OF ENGINEERING DRAWINGS

2.20.1 REQUIREMENTS

Selected-part drawings shall be used only when an existing vendor or Government standard item cannot be used as supplied, and then only after the vendor has rejected a request to make the selection and assign a new catalog number for the item as selected. The drawings shall contain sufficient data to allow procurement of the item as supplied from the original or other source (as in a specification control drawing), plus all selection information necessary to make the selection. All selection information shall be clearly shown in detail and marked in some manner to distinguish this information from any other that may be supplied. It shall also specify reidentification of the selected item with a number which shall be or include the drawing number of the selected part drawing. A selected part drawing shall be identified by the words "SELECTED PART", above the title block.

2.21 SKETCH DRAWING

A drawing used by engineers and designers for non-production work or to facilitate development or trial work where there is no probability of a need for fixed records.

2.21.1 REQUIREMENTS

The sketch drawing should be prepared on a standard size format to facilitate storage and reproduction. All sketch drawings shall be identified by a number assigned by the design section originating the drawing, and the recording of the drawings shall be the responsibility of the originating design section.

2.22 TABULATED DRAWING

A tabulated drawing depicts similar items which, as a group, have constant and variable characteristics. A tabulated drawing precludes the preparation of an individual drawing for each item.

2.22.1 REQUIREMENTS

The statement of requirements shall be as complete as that required by Paragraph 2.6.1 for a detail part. The variables between the items shall be tabulated, and the constant characteristics shall be depicted or stated once. Normally, a pictorial representation of a single item is shown, with variable dimensions coded by means of letters used as headings for columns in the tabulation. The variables are entered in the table under the appropriate headings and on the same line as the identifying number or letter of the item to which they pertain.

TYPES AND DEFINITIONS OF ENGINEERING DRAWINGS

2.23 UNDIMENSIONED DRAWING

An undimensioned drawing is a drawing which provides information for fabricating and inspecting parts.

2.23.1 REQUIREMENTS

The drawing is prepared on dimensionally stable material and the items such as printed wiring masters, decal masters, pattern detail, etc., are depicted by accurate scale layouts rather than by conventional dimensional methods.

2.24 WIRE HARNESS DRAWING

A wire harness drawing defines a group of wires laced together, in advance of final assembly, in a specified configuration providing electrical connection with a unit or assembly.

2.24.1 REQUIREMENTS

A single line shall be used to depict the harness and shall show all dimensions necessary to define the harness form and termination points. The drawing shall also include a wire data tabulation of wire numbers, circuit reference designations, color codes, lengths, material specifications, and other data, as necessary. Included in note form should be instructions, or references thereto, for the preparation and installation of the harness, associated schematic diagram, and the wiring diagram.

2.25 INSTALLATION CONTROL DRAWING

An installation control drawing sets forth dimensional information for an item in terms of area and space, sway and access clearances, pipe and cable attachments required for the installation, and cofunctioning of the item to be installed with related items.

2.25.1 REQUIREMENTS

An installation control drawing shall include overall and principal dimensions in sufficient detail to establish the limits of space in all directions required for installation, operation, and servicing. The amount of clearance required to permit the opening of doors or the removal of plug-in units shall be included. Clearance for travel or rotation of any moving parts shall be shown, including the centers of rotation, elevation, and depression; angles of train in azimuth; and radii from each pivot point to the end of each rotating element involved in clearance determination.



TYPES AND DEFINITIONS OF ENGINEERING DRAWINGS

2.26 SYSTEM FUNCTIONAL DRAWING

A System Functional Drawing (SFD) depicts in schematic and/or block diagram format the configuration of a system to the component and/or assembly level without necessarily considering the actual physical size, shape, or detailed locations.

2.26.1 REQUIREMENTS

The functional configuration of a system shall be described in schematic/block diagram format; the general location of the equipment will be shown, and interfaces with other design organizations shall be identified. Nomenclature, part identifying numbers, and component/assembly specification numbers shall be specified as required to define the functional configuration of the system.

DRAWING FORMAT

3.1 GENERAL

KSC engineering drawings will be prepared on KSC formats. Preprinted forms are listed below and shall conform to the instructions for format completion as detailed in the following paragraphs and instructions for entries, drawing preparation, and notations as detailed in Section 4.

3.1.1 FINISHED FORMAT SIZES (INCHES)

Size (Ltr)	Width	Length	Margin	Form No.
A (Vert)	11	8 1/2	1/ 4(Horiz) 3/ 8(Vert)	21-2
A (cont sh)	11	8 1/2	1/4	21-2B
A (Horiz)	8 1/2	11	1/4	21-2A
B	11	17	3/ 8	21-4
C	17	22	1/2	21-5
D	22	34	1/2	21-6
D (with PL)	22	34	1/2	21-6A
E	34	44	1/2	21-8
F	28	40	1/2	21-9
J	34	50	1/ 2	21-10
J (with PL)	34	50	1/2	21-10A
H (Roll size)	28	48 Min 144 Max	See Para. 3.3	
Record of Sheets Revised	11	8 1/2	1/ 4	21-109

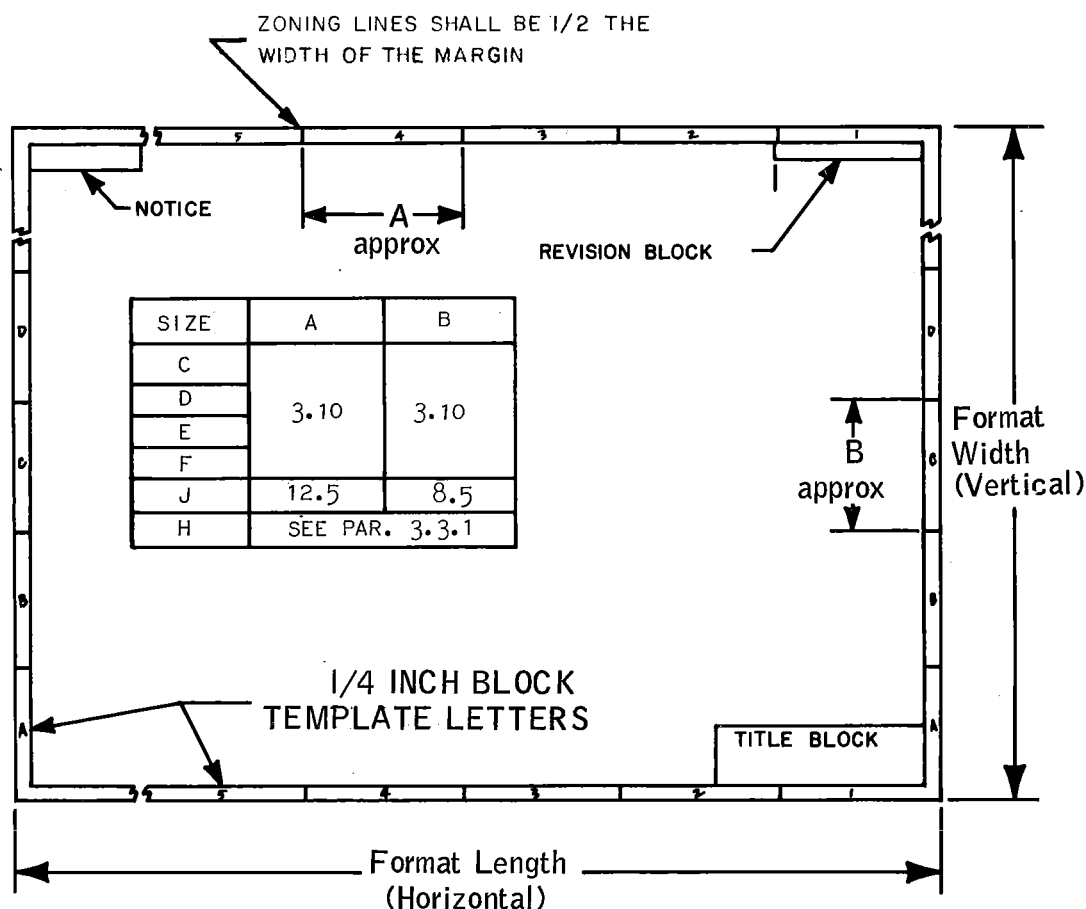
DRAWING FORMAT

3.2 BASIC FORMAT

The formats listed in paragraph 3.1.1 shall be altered to the extent of erasing the pre-printed place of origin, when necessary, and in its place, template letter "KENNEDY SPACE CENTER, FLORIDA" in letters 0.125 inch high.

3.2.1 ZONING OF DRAWINGS

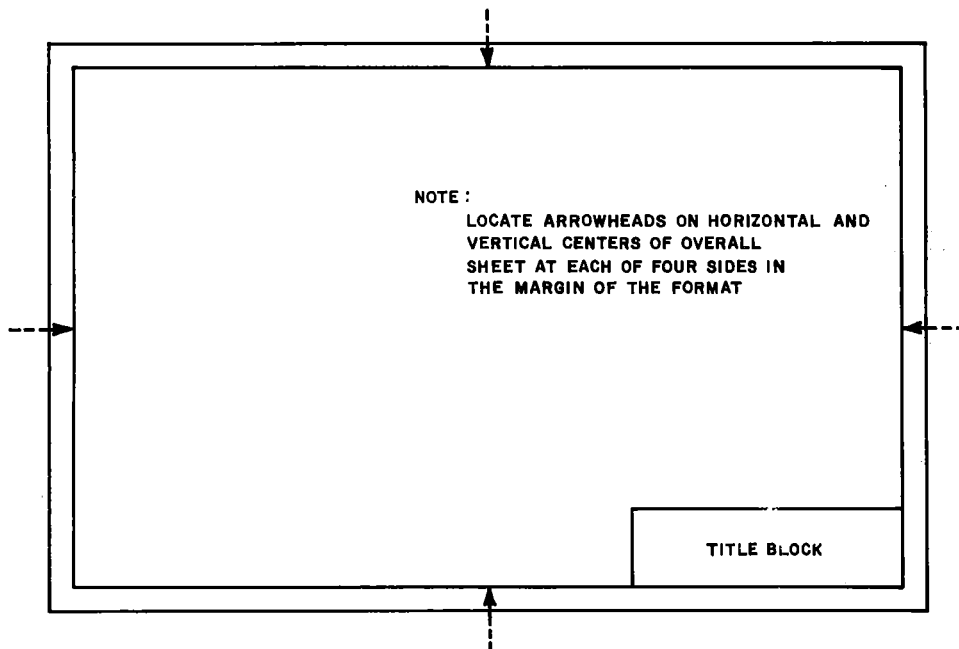
All KSC drawing formats with the exception of sizes A and B will be zoned. When zone markings are not preprinted on existing formats, zone areas shall be added as detailed below, with vertical zones uniformly spaced and identified alphabetically from the bottom of the drawing, and horizontal zones uniformly spaced and identified numerically beginning at right-hand edge of the drawing.



DRAWING FORMAT

3.2.2 MICROFILMING ALIGNMENT ARROWHEADS

Alignment arrowheads shall be used on all drawings. When they are not preprinted, they shall be entered in the margin of the "basic format" as illustrated below. Roll-size application of alignment arrowheads shall be as outlined in Paragraph 3.3.3.



3.3 ROLL-SIZE FORMAT

A roll-size drawing shall have all the "basic format" requirements as preprinted forms, in addition to the requirements outlined in Paragraph 3.3.1, 3.3.2 and 3.3.3. Roll-size drawings should be used only when authorized.

3.3.1 ZONING

Zone areas for a roll-size drawing shall be spaced 11 inches on the horizontal, and 8 1/2 inches on the vertical, and shall be identified in the same manner as described in Paragraph 3.2.1.

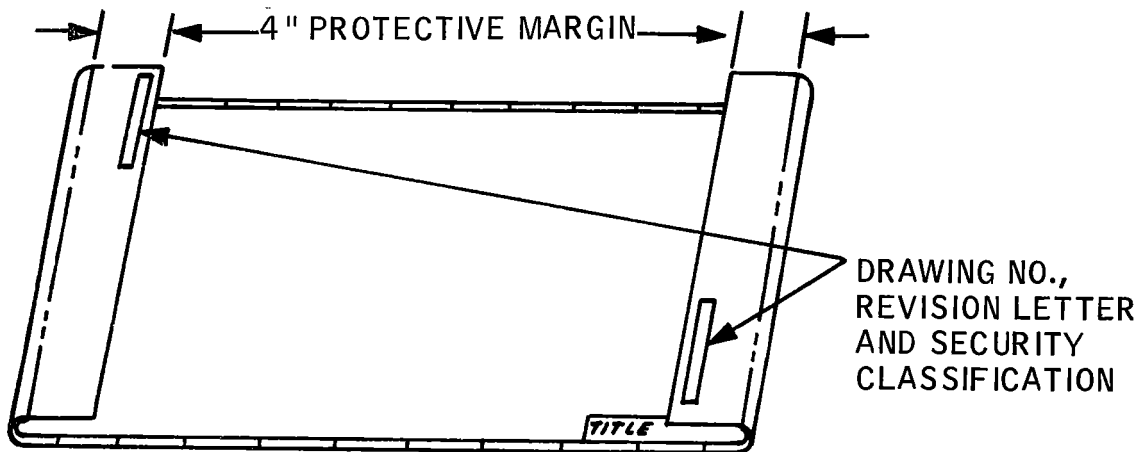
3.3.2 MARGINS

A roll-size drawing shall have a 1/2 inch horizontal margin and a 4 inch vertical protective margin, included within the min/max length, as illustrated.



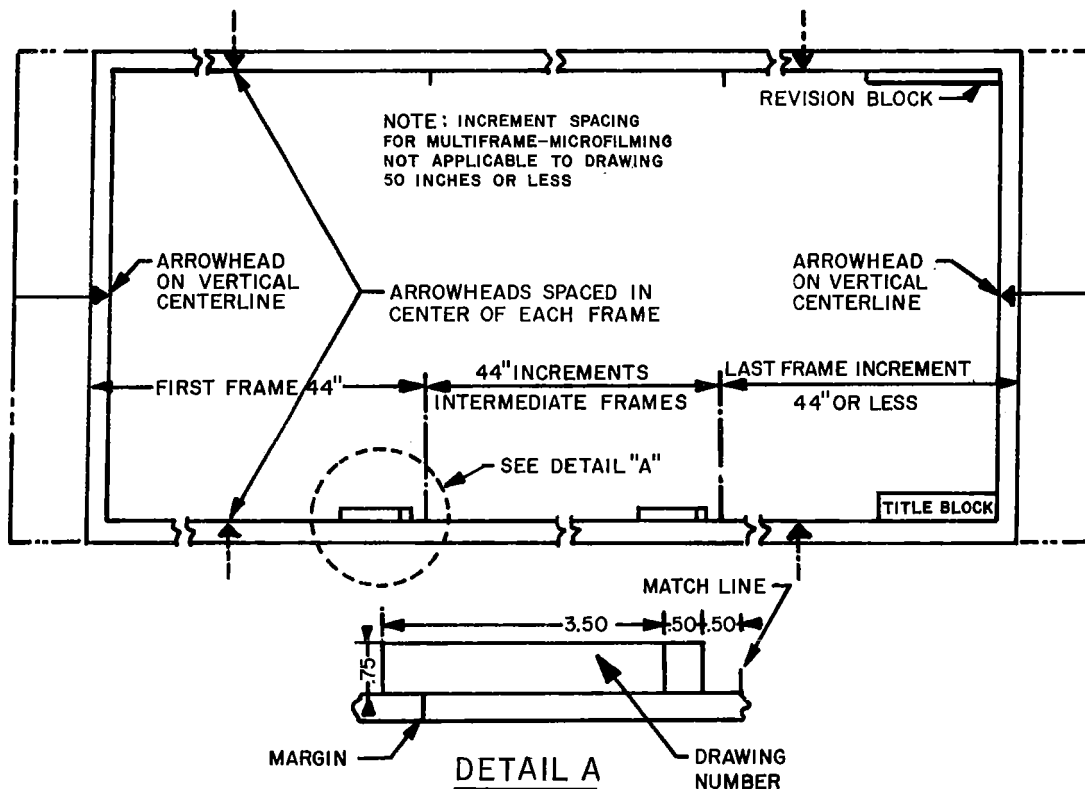
DRAWING FORMAT

3.3.2 (Contd)



3.3.3 MATCH LINES ALIGNMENT ARROWHEADS AND DRAWING NUMBER BLOCKS

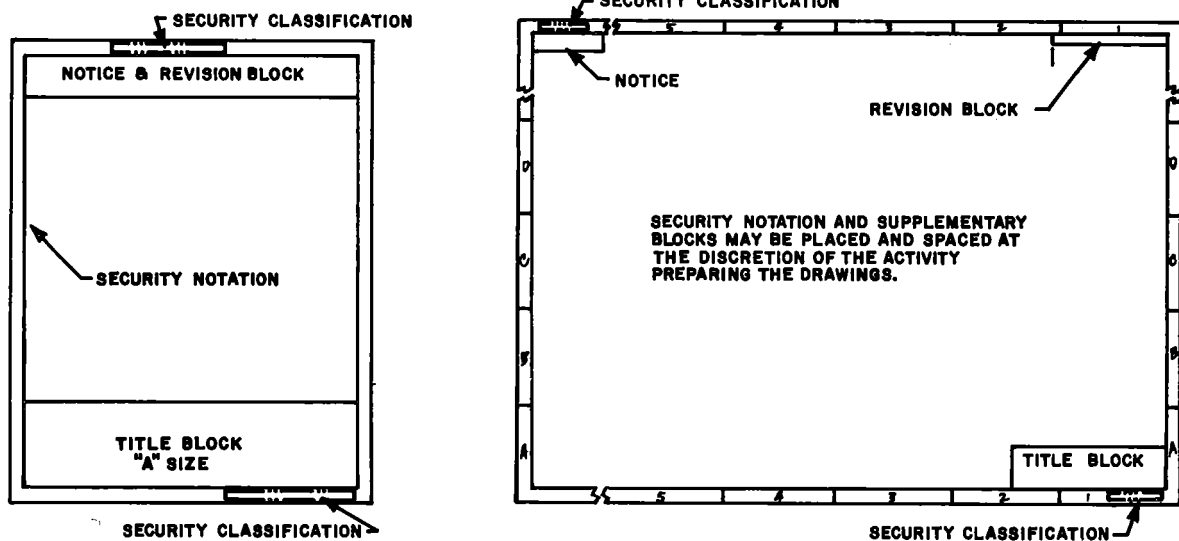
Match lines, used to facilitate realignment of multiframe reproductions, shall be placed on a roll-size drawing in addition to alignment arrowheads and drawing number blocks entered within each frame as illustrated below.



DRAWING FORMAT

3.4 SECURITY CLASSIFICATION AND NOTATION

The security classification and notation shall be shown on all drawings warranting a security classification in locations indicated in the following examples and in accordance with the DOD Industrial Security Manual for Safeguarding Classified Information (5220.22-M).



3.4.1 LOCATION ON ROLL-SIZE FORMAT

Security classification shall also be shown on both ends of the reverse side of a roll-size format in the locations indicated by the example in Paragraph 3.3.2.

3.5 ASSOCIATED LISTS

3.5.1 SEPARATE PARTS LISTS

Parts lists intended for mechanization shall be prepared separately, rather than integral with drawing, on A-size paper format.

SECTION 3

PAGE 3-6

DATE 15 Sept. 1965

KSC



MANUAL

Ground Support Equipment

DRAWING FORMAT

3.5.1 (Contd)

NOTE

Parts lists formats will be supplied by KSC when a basic format has been approved and issued.

3.5.2 INTEGRAL PARTS LIST DRAWING

If it is necessary to include a parts list on a drawing and the particular format selected does not contain an integral parts list, applique KSC Form 21-11 may be used.

REVISED 15 Sept. 1969



DRAFTING PRACTICES AND ROUTINES

4.1 GENERAL REQUIREMENTS

The requirements contained in this section shall be employed in the preparation of drawings to achieve uniformity. Method of projection, sectioning and scale shall be in conformance with MIL-STD-100 and the specific instructions contained herein.

4.2 SIGNATURES, APPROVALS, DATES, AND BLOCK ENTRIES

Unless otherwise specified by contract or order, entries shall be made in the title and revision blocks (Fig. 4.2.1) as follows:

Contractor

- ① a Enter the date that the drawing was completed (e.g., Jan. 16, 1965).
- ① b Signature of draftsman completing drawing.
- ① c Drawing title (per section 6).
- ① d Enter scale of drawing.
- ① e Enter calculated unit weight in decimal form (see Para. 4.5). The note "See Tab." shall be printed in this block on tabulated drawings.
- ① g Enter the drawing number.
- ① h Enter applicable sheet number (see Para. 4.11).
- ① k Enter NASA design section symbol.
- ① m Enter applicable tolerance.

e. g. Decimals

.xx ± .03 - indicates 2 place decimal dimensions shall have ± .03 tolerance unless otherwise specified.


.xxx ± .010 - indicates 3 place decimal dimensions shall have ± .010 tolerance unless otherwise specified.

DRAFTING PRACTICES AND ROUTINES

4.2 (Contd)

Fractions - $\pm 1/32$ - indicates fractional dimensions shall have $\pm 1/32$ tolerance unless otherwise specified.

Angles - $\pm 1^\circ$ or $\pm 0^\circ 30'$ As Required.

- ① n Enter the material and applicable specification. When there is insufficient room in the block, a flag symbol () and the referenced note number shall be placed in the block and the requirements shall be called out in a note. When the material block is not applicable, a horizontal line shall be drawn thru the center of the block.
- ① p Enter heat treatment requirements and specifications. Where there is insufficient room or the block is not applicable, the procedure described in ① n shall be used.
- ① r Enter the final protective finish and applicable specification. Where there is insufficient room or the block is not applicable, the procedure described in ① n shall be used.
- ① s List applicable next assembly (s) at time of initial release. Additional blocks may be added if required. (see para 4.2.1).
- ① t Enter CEI number for which the equipment is used for each entry in ① s. (see para 4.2.1)
- ① u Enter Design Activity Code Identification Number. To be assigned by NASA. (See Section 7).
- ② Signature of Checker (see para 4.2.1)
- ③ Signature of Design Engineer
- ④ Signature of Drafting Supervisor
- ⑤ Signature of Stress Engineer (Not applicable to "A" size format.)

DRAFTING PRACTICES AND ROUTINES

4.2 (Contd)

NASA

- 7 Signature of Checker (see para 4.2.1)
- 8 Signature of Project Engineer
- 9 Signature of Technical Supervisor or his designated representative.
- 10 Signature of Branch Chief or his designated representative.

Revisions

- 1 Enter Zone, Symbol, Description, and Date.
- 3 If drawing is revised by Contractor, Design Engineer shall initial change.

Microfilm

- 6 a All releases that have been microfilmed shall have the symbol "F" entered.
- 6 b As subsequent changes are microfilmed the letter "F" will be placed adjacent to the latest change.

4.2.1 TITLE BLOCK ENTRIES

Title block entries on all KSC drawing formats conform to paragraph 4.2 with the exception of the following:

- 1 s Vertical "A" size formats position these entry blocks adjacent to the revision block. Other than this, entries shall conform to paragraph 4.2.
- 1 t
- 2 "A" size formats title this entry block "Tracer". Erase and hand letter in its place "Checker".
- 7 Applicable to "A" size only. Entry block is titled "Checker".

DRAFTING PRACTICES AND ROUTINES

PART No.		REVISIONS			
		DESCRIPTION	DATE	APPROVAL	
		①	①	③	
		②	①	③	

TO BE INITIALED BY
NASA AND CONTRACTOR
IF REVISED BY
CONTRACTOR

CONTRACTOR OR NASA

1- DRAFTSMAN

6- DOCUMENTATION CONTROL

CONTRACTOR

1. DRAFTSMAN

2. CHECKER

3. DESIGN ENGINEER

4. SUPERVISOR

5. STRESS ENGINEER

NASA

7. CHECKER

8. PROJECT ENGINEER

9. TECHNICAL SUPERVISOR

10. BRANCH CHIEF

UNLESS OTHERWISE SPECIFIED		ORIGINAL DATE OF DRAWING		JOHN F. KENNEDY SPACE CENTER, NASA	
DIMENSIONS ARE IN INCHES		① a		① c	
TOLERANCES ON FRACTIONS		① b		① d	
DECIMALS		① m		① e	
ANGLES		① n		① f	
MATERIAL		① o		① g	
HEAT TREATMENT		① p		① h	
FINAL PROTECTIVE FINISH		① q		① i	
SEE ENGINEERING RECORDS		DRAFTSMAN ① b	CHECKER ④	DATE ① u	DWG. SIZE ① g
① s	① t	CHECKER ②	STRESS ENGINEER ⑤	CODE ① u	J
NEXT ASSY	USED ON	ENGINEER ③	ENGINEER ⑥	UNIT WEIGHT ① e	SHEET ① h
APPLICATION		SUBMITTED ⑨	APPROVED ⑩	SCALE ① d	OF

① k

DISTR. CODE

Figure 4.2-1. Typical Title and Revision Blocks

DRAFTING PRACTICES AND ROUTINES

4.3 ASSEMBLY OR INSTALLATION DRAWINGS

4.3.1 ITEM IDENTIFICATION

All items shall be identified on the field of drawing. Unless contract provisions state otherwise, items shall be identified by an item (find) number on the field of the drawing which is cross-referenced to the identifying part number appearing on the list of material.

4.3.2 LIST OF MATERIAL

The KSC Drawing Formats which include a "List of Material" require a minor revision as follows until a new form is available.

NO REQD PER ASSY	ZONE	FIND NO OR ITEM NO	MFR CODE	PART OR STOCK NO			
ASSY DASH NO				DRAWING NO			
UNLESS OTHERWISE SPECIF							
DIMENSIONS ARE IN INCHES TOLERANCES ON <div style="display: flex; justify-content: space-between;"> FRACTIONS DECIMALS </div>							
SEE ENGINEERING							

REMOVE →

Erase "No. Required Per Assy." and extend existing vertical lines thru this block. Add "And No. Required" to "Assy. Dash No."

ASSY DASH NO AND NO REQD	ZONE	FIND NO OR ITEM NO	MFR CODE	PART OR STOCK NO			
				DRAWING NO			
UNLESS OTHERWISE SPECIF							
DIMENSIONS ARE IN INCHES TOLERANCES ON <div style="display: flex; justify-content: space-between;"> FRACTIONS DECIMALS </div>							
SEE ENGINEERING							

ADD →



DRAFTING PRACTICES AND ROUTINES

4.3.2.1 Applicable Columns


[illegible]

- A - Enter assembly dash number (see Section 7).
- B - "No. Required" Column - Enter total quantity of each item required to complete one assembly or system. Quantity of the line describing the main assy. (-1) shall remain blank.
- C - "Zone" Column may be used to locate the item on the field of the drawing where applicable. If the item is called for in more than one zone, the zone column shall be left blank.
- D - "Find or Item Numbers" shall run consecutively from one beginning with the first item or component listed (i.e. 1, 2, 3, 4, 5, etc.).
- E - "Mfg. Code" - Whenever NASA part numbers have not been assigned to an item, the list of material shall include all of the required procurement information such as manufacturers name, address, and part identification number. The manufacturer shall be identified by his "code identification number" entered in this column (See Cataloging Handbook H4-1). If the manufacturer has not been assigned a code identification number, a note flag (▷) shall be

DRAFTING PRACTICES AND ROUTINES

4.3.2.1 (Contd)

entered in this column and the appropriate information displayed in the accompanying note. Government or industry standard part numbers (AN, MS, etc.) do not require Code Identification Numbers.

- F - The "Part or Stock No., Drawing No." Column shall list the identifying number for every entry on the list of material. i.e., drawing and dash no. (see Section 7 for dash number assignment), government or industry standard and dash no., complete catalog no. of vendors part, etc.
- G - These columns shall be left blank.
- H - In the "Description" columns enter the noun or noun phrase applicable to each item. In cases where items are detailed on the assembly, the top line in this column shall define the material (ex. 316 CRES SH, 4340 Steel B, etc.) and the second line specifies the nomenclature (ex. Cover, Plate, Brace, etc.).
- J - "Stock Size" shall identify the structural size and shape of material defined in "H" where applicable. (i.e. 10 GA., 2 3/4 OD x 5/32, 2 1/4 x 3 x 1/2, etc.).
- L - The "Material Specification" column shall list the Government or NASA Specification (see Section 24) for materials called out in "H" and "J". For materials common to several items or where there is insufficient room within the column, a note flag () and note may be used.
- M&N - "Finish Code" and "Heat Treatment" columns are applicable when the specification listed in "L" contains finish code and heat treatment choices requiring selection.

"Unit Weight" - Unless entries in this column are specifically requested, the unit weight of components or items shall not be tabulated. The unit weight of the assembly shall be listed per (Section 4, paragraph 4.5) in the unit weight block in the lower right hand corner of the title block of the sheet containing the List of Material.

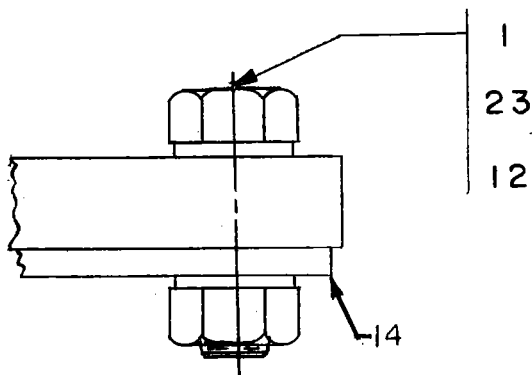


DRAFTING PRACTICES AND ROUTINES

4.4 CALLOUTS ON DRAWINGS

4.4.1 ITEM (FIND) NUMBERS

Item (Find) numbers cross referenced to the item numbers of the list of materials shall appear on the field of the drawing as shown below. The item number shall be 1/8 min. high.

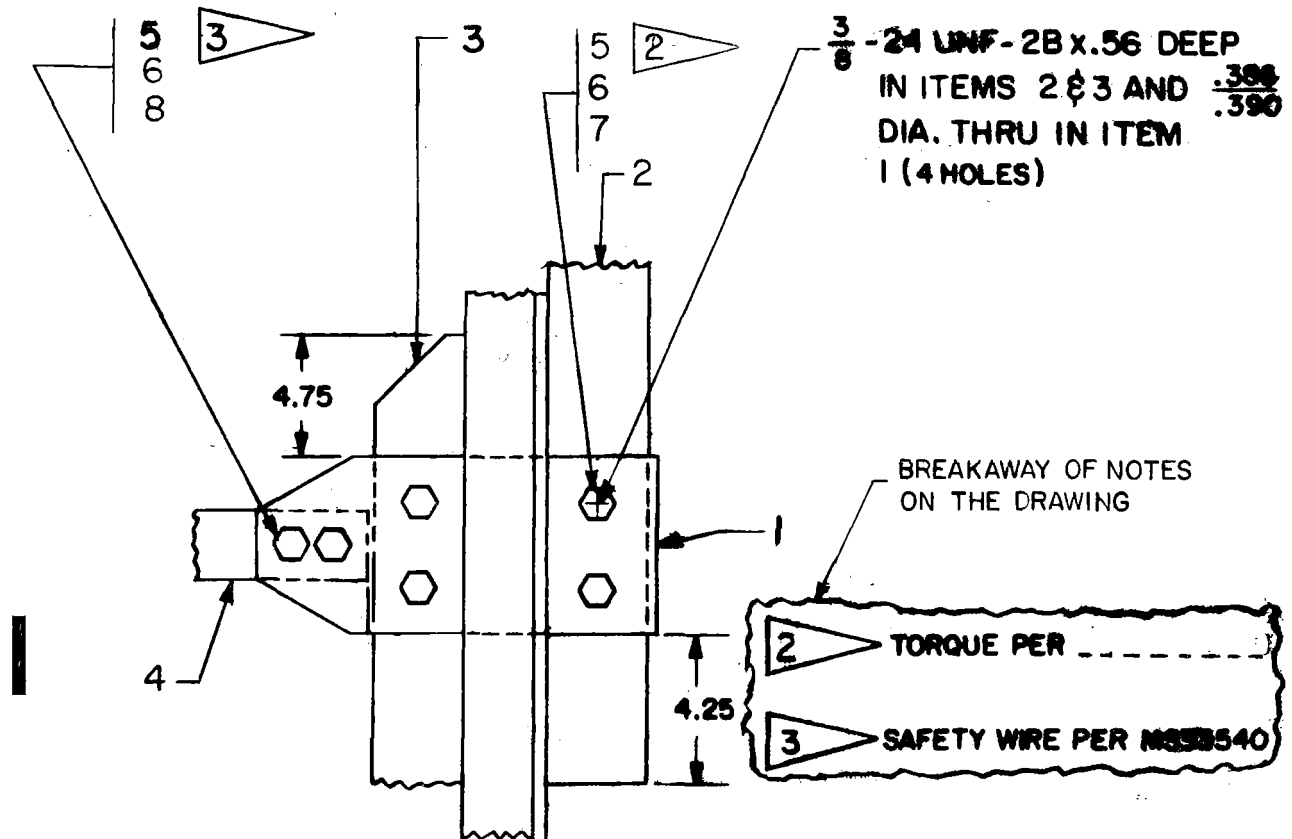


Assembly information may be noted either on the field of the drawing or by a "flag" to a drawing note as shown in Para. 4.4.1.1; however, none of the information tabulated in the list of material shall be repeated alongside of the Item Find Number.

DRAFTING PRACTICES AND ROUTINES

4.4.1.1 Alignment of Item (Find) Numbers

The draftsman shall make a reasonable effort to align the item (find) number in an orderly arrangement (numbers need not run consecutively) to aid in the readability of the drawing.



4.4.2 SYSTEM FIND NUMBERS AND REFERENCE DESIGNATIONS (Section 16)

Assigned system find numbers and electrical reference designations shall be used for all schematic components and end connections. The system find numbers and electrical reference designations refer to the function of the component in the system and are used for one particular part only. The system find numbers and electrical reference designations will be assigned by the KSC design activity.



DRAFTING PRACTICES AND ROUTINES

4.5 WEIGHT OF COMPONENTS

The weight of the assembly or detail part will be entered on the drawing in the appropriate place in the title block. The number of significant figures that will represent the weight shall be in accordance with the following table:

Calculated Weight	Entry on Drawing X Indicates Number of Significant Figures
Less than 0.05	--
0.05 to 0.15	0.1
0.15 to 10.0	X.X
10.0 to 100	XX
100 to 1000	XX0
More than 1000	XX00

Hence a calculated weight of 1237 lbs. shall be entered on the drawing as 1200 lbs.

DRAFTING PRACTICES AND ROUTINES

4.6 STANDARD DRAFTING PRACTICES

KSC-STD-168, Drawing Terms and Tolerances (see Section 25) describes permissible tolerance variations in respect to factory oriented machined and sheet metal parts and may be utilized in its entirety to define permissible variations as described or, the drawing (s) may definitely state (by dimensions, form tolerances or notes) those portions of KSC-STD-168 that are applicable. In either case the draftsman, designer, and engineer shall be completely familiar with the contents of KSC-STD-168 in order to evaluate its required usage and effect.

When referenced by drawing note, this standard defines the variations permissible unless modified (either tighter or looser tolerances) by drawing dimensions, form tolerances, etc., and is an effective means of establishing control and interpretation of implied tolerances (squareness, flatness, etc.).

4.6.1 OTHER PRACTICES

The drafting practices for defining specific detail requirements (i.e. thread undercuts, welding, riveting, etc.) shall be as described in this manual wherever practical.

4.7 SPECIFYING MATERIALS, FINISHES AND PROCESSES

4.7.1 MATERIALS

Design and application considerations as well as economic factors shall govern the selection and use of materials. Wherever possible the materials listed in Section 24 shall be specified. The drawing shall completely define the material requirements; applicable type, grade, class or conditions shall be described.

4.7.2 FINISHES

■ Applied finishes (Plating, Paint, Anodize etc.) when required, shall be per Section 9 wherever possible and shall be specified on the drawing in the appropriate block or by drawing note.

4.7.3 MACHINE FINISHES

Machine finishes on surfaces requiring finish control shall be specified per Section 8.



DRAFTING PRACTICES AND ROUTINES

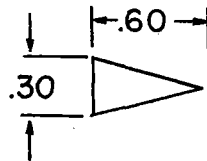
4.8 DRAWING NOTES

See Section 9 for drawing notes and application.

Drawing notes must be clear and specific in wording to avoid misinterpretation. All notes are to be numbered consecutively from the top down.

4.8.1 TYPES OF NOTES4.8.1.1 Specific Notes

When a note pertains to a particular portion of a part or group, it shall be considered a specific note. Specific drawing notes may be referenced by placing a note number within a triangular flag located on the field of the drawing where the specific note applies. The specific note in the list of notes shall also have its note number placed within a triangular flag. The size of the triangular flag shall be:

4.8.1.2 General Notes

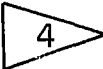
See below for example of general and specific drawing notes.

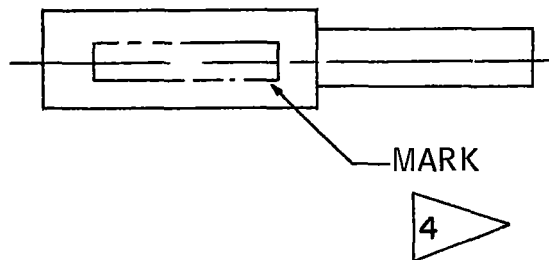
1. DRAWING TERMS AND TOLERANCES PER KSC-STD-168.
2. $\sqrt{125}$ UNLESS OTHERWISE SPECIFIED.

DRAFTING PRACTICES AND ROUTINES

4.8.1.2 (Contd)

3. FINISH ANODIC (SULPHURIC ACID) PER 7.2.1 OF MIL-STD-171.

I  MARK 75MXXXXX PER KSC-STD-E-0015.



4.9 IDENTIFICATION AND LOCATION OF VIEWS AND SECTIONS

4.9.1 IDENTIFYING LETTERS

Identifying letters for sections, views, and details shall be assigned in alphabetical sequence. For sections and views use double letters A-A thru Z-Z. In cases where the single alphabet is exhausted multiple letters may be used (i.e. AA-AA, AB-AB, etc.). For encircled details use single letters A thru Z and continue AA, AB, AC if the single alphabet is exhausted. The letters I, O, and Q shall not be used.

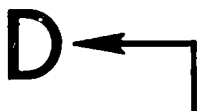
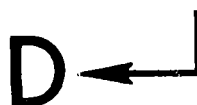
In no case shall a section, view or detail of the same drawing carry the same identifying letter. If section A-A exists, there shall be no View A-A or Detail A.



DRAFTING PRACTICES AND ROUTINES

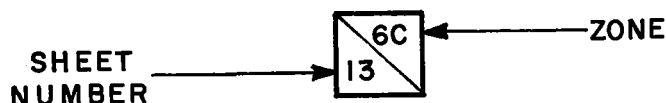
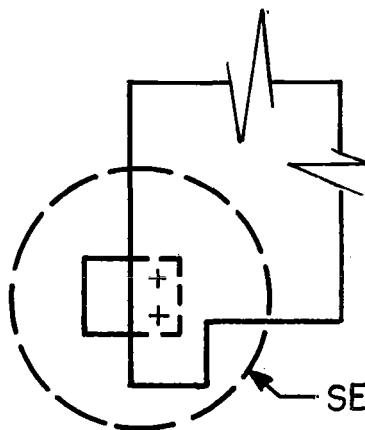
4.9.1 (Contd)

Identifying letters shall be 1/4 inch block letters with descriptions 3/16 inch block letters and underlined as shown.


SECTION D-D


4.9.2 LOCATION

Drawings shall cross-reference a view, section or detail and the portion of the drawing that it clarifies by the use of a diagonally divided square block as shown. Size of block should be uniform within the same drawing.


DETAIL G


SEE DETAIL G

DRAFTING PRACTICES AND ROUTINES

4.10 LEGIBILITY AND REPRODUCIBILITY

To assure that microfilms of acceptable quality can be produced the following practices and techniques should be observed on production drawings.

Drawings shall be prepared in pencil unless otherwise instructed.



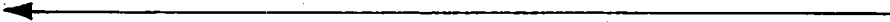
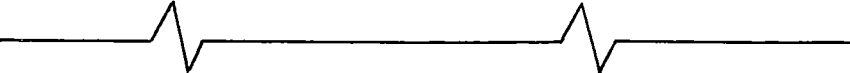
4.10.1 LINES

4.10.1.1 Quality

Lines which are very thin or which are not uniformly opaque on the original drawing will become ragged in a print made from microfilm. Wider or denser portions of lines may increase in width while thinner or less dense portions may disappear completely. It is necessary therefore that all lines on a drawing be uniformly opaque.

4.10.1.2 Width

Since all lines must be uniformly opaque, any desired contrast between object lines and other lines can be obtained only by a variance in the relative width of lines. Relative widths for standard types of lines are shown in the following table:

CENTER LINE		THIN
DIMENSION		THIN
LEADER		THIN
BREAK (LONG)		THIN

DRAFTING PRACTICES AND ROUTINES

4.10.1.2 (Contd)

SECTIONING AND _____ THIN
EXTENSION LINE

PHANTOM _____ MEDIUM

HIDDEN _____ MEDIUM

STITCH LINE _____ MEDIUM

DATUM LINE _____ MEDIUM

OUTLINE OR _____ THICK
VISIBLE LINE

BREAK (SHORT)  THICK

CUTTING PLANE
OR
VIEWING PLANE   THICK

VIEWING PLANE
(OPTIONAL)   THICK

CUTTING PLANE
FOR COMPLEX OR
OFFSET VIEWS  THICK

DRAFTING PRACTICES AND ROUTINES

4.10.1.3 Spacing

Lines spaced close together (cross hatching, etc.) have a tendency to flow together on successive generations of microfilm reproductions. For this reason a minimum spacing of .06 inches between lines shall be maintained.

4.10.2 LETTERING

Lettering size, both hand lettering and template lettering, shall conform to the minimum sizes listed below. Since hand lettering is subject to considerable non-uniformity, well rounded, clearly defined and properly spaced lettering is essential. *Pinched or curled letters and numerals tend to close in on microfilm images and become illegible or resemble other characters.*

<u>Item</u>	<u>Minimum Character Size</u>		<u>Method</u>
	<u>A, B & C Size</u>	<u>D, E, F, & J</u>	
Drawing Number	.25	.25	Template
Title	.18	.25	Template
Subtitle & View Titles	.12	.18	Hand
Field of Dwg., Notes & Revisions	.12	.16	Hand
"NOTES" (Heading)	.18	.18	Hand
Vertical Spacing			
Between Line of Notes	.06	.09	--
Between Notes	.12	.18	--
Title Block Entries	.12	.16	Hand
List of Material	.12	.16	Hand
Find No.	.12 .12	.12 .16	Template Hand
Ref. Des., Etc.	.12 .12	.12 .16	Template Hand

Decimal points, dashes, etc. shall be bold and shall be given one full letter space.

DRAFTING PRACTICES AND ROUTINES

4.10.2.1 Typewritten Lettering

Typewriters (electric recommended) equipped with .12 inch high, all capital gothic type and having ten characters per inch spacing may be used for all sizes of drawings. Ribbons must be carefully chosen in order to obtain opaque letters and yet avoid feathered edges or smudging characteristics. On typewritten A size formats the drawing number may be typed.

4.10.2.2 Preprinted Lettering

Rubber stamps and appliques must be approved and used with extreme care to assure sharp definitions.

4.10.3 SIGNATURES AND DATES

Signatures and especially dates are often very important on drawings. In order to obtain legibility, signatures and dates shall be executed with the same care as given to lettering and lines.

4.10.4 SYMBOLS

The same general rules apply to symbols as apply to lines and lettering. The symbols as defined in KSC-STD-152 (Section 14) shall be reproduced to the size shown in that document. All other symbols (geometric tolerance, welding, etc.) shall be delineated with microfilm reproduction in mind.

4.10.5 CROSS-SECTION AREAS

Section lines rather than shading shall normally be used when it is necessary to indicate cross-sectional areas. Wide opaque areas will not reproduce on microfilm therefore shading over 1/8" wide shall not be used on A, B, & C size drawings nor over 1/4" wide on D, E, F, & J size drawings. Generally, the simplified section convention of MIL-STD-100 shall be used.

DRAFTING PRACTICES AND ROUTINES

4.11 NUMBERING OF MULTISHEET DRAWINGS

Each sheet of a multisheet drawing shall be identified by the drawing number and the sheet number. The total number of sheets shall be shown on sheet 1 and the remaining sheets shall be numbered consecutively as follows:

sheet 1 - SHEET 1 OF 45
 (SHEET 1 OF 1 FOR A SINGLE SHEET DRAWING)
sheet 2 - SHEET 2
sheet 3 - SHEET 3
final sheet - SHEET 45 OF 45

If a new sheet is added to the package by revision, it shall follow the procedures set forth in paragraph 10.6.1.2.



DIMENSIONING AND TOLERANCING

5.1 GENERAL

Dimensioning and tolerancing shall be in accordance with MIL-STD-8, Dimensioning and Tolerancing.

KSC-STD-168, Interpretation of Drawing Terms and Tolerances, (see Section 25) may be used in conjunction with this document where applicable.

General tolerance ranges are listed in various design sections throughout the KSC Manual for the designers consideration. It should be stressed that, in the interest of cost, flexibility and time, the tolerance should be as broad as the design will allow.

DRAWING TITLES AND ITEM NOMENCLATURE

6.1 GENERAL

The nomenclature for title blocks on drawings and for parts or items detailed thereon shall be established in accordance with the procedures outlined in this section.

The primary purpose for establishing nomenclature is to describe the part or item and to distinguish between similar parts or items. The reason for arranging nomenclature in a specific manner is to give proper sequence to common denominators of like items and to permit effective use of a mechanized storage and retrieval system for item information.

Item nomenclature should be brief and simple yet complete enough to serve its intended purpose.

6.2 PROCEDURE

The drawing title or item nomenclature may consist of two parts as described by the following subparagraphs.

6.2.1 FIRST PART

The first part shall be the item name and shall consist of a basic name and modifiers as required. Section A (alphabetic Index of Names) Part 1, of the Federal Item Identification Guides for Supply Cataloging, published as Cataloging Handbook H 6-1 Section A, shall be used as a guide in establishing the item name.

6.2.1.1 Basic Name

The basic name shall be a noun or noun phrase. This identifying noun or noun phrase shall establish the basic concept of an item.

Examples: Cabinet
Pump
Panel Assembly
Valve

6.2.1.2 Modifiers

A modifier may be a single word or a modifying phrase. The first modifier shall serve to narrow the area of concept established by the basic name and succeeding modifiers must continue a narrowing of item concept by expressing a different type of characteristic. A



DRAWING TITLES AND ITEM NOMENCLATURE

word directly qualifying a modifying word shall precede the word it qualifies, thereby forming a modifying phrase, for example, ELECTRICAL EQUIPMENT. The word "ELECTRICAL" qualifies the word "EQUIPMENT" and precedes it in the modifying phrase. A modifier shall be separated from the basic name by a comma and from any preceding modifier by a comma.

Examples: Cabinet, Electrical Equipment
Pump, LOX Transfer
Panel Assembly, LOX Control
Valve, Butterfly

6.2.2 SECOND PART

The second part shall be separated from the first part by a dash. The second part shall consist of additional modifiers or modifying phrases as required to further identify an item and distinguish it from similar items that perform the same general function, for example, modifiers indicating method of operation, pertinent dimensions or size, function, rating, location, etc.

A modifier shall be separated from a preceding modifier by a comma.

Examples: Cabinet, Electrical Equipment - Fuel Transfer
Pump, LOX Transfer -1000 GPM
Panel Assembly, LOX Control-LC-39
Valve, Butterfly-Pneumatic Actuated,
6-inch, 300 Pound

6.3 RULES

The following general rules apply to all drawing titles and item nomenclature:

- a. No abbreviation of any portion of the name (first part) shall be made, except those necessarily used trademarked names (see paragraph d) and the words ASSEMBLY (ASSY), SUBASSEMBLY (SUBASSY), or INSTALLATION (INSTL).
- b. Abbreviations may be used in the second part of the nomenclature; however, they shall conform to the abbreviations listed in section 13 of this manual. In general, the use of abbreviations should be avoided.



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DRAWING TITLES AND ITEM NOMENCLATURE

- c. An ambiguous noun, or one which designates several classes of items, shall not be used alone, but shall be used as part of a noun phrase.

Examples: Correct

Incorrect

SOLDERING IRON	IRON, SOLDERING
HEATING ELEMENT	ELEMENT, HEATING
ANTISEIZE COMPOUND	COMPOUND, ANTISEIZE

- d. A trademarked or copyrighted name shall not be used as the noun or noun phrase, unless the technical name is extremely difficult or no other name is available.

Example: Correct

Incorrect

FREON 12

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- e. When an item is neither a container nor a material, but its name involves the use of a noun which ordinarily designates a container or a material, a noun phrase shall be used as the basic name.

Examples: Correct

Incorrect

JUNCTION BOX
CABLE DRUM
SOLDERING IRON

BOX, JUNCTION
DRUM, CABLE
IRON, SOLDERING

- f. The following words shall not be used alone but may form a part of a noun phrase:

acid	element	machine	powder
apparatus	equipment	mechanism	shop
assembly	fluid	mix	subassembly
assortment	group	mixture	tackle
attachment	instrument	oil	tool
compound	kit	outfit	unit
device	liquid	plant	vehicle



DRAWING TITLES AND ITEM NOMENCLATURE

Examples: Tool Kit
Machine Shop

- g. The conjunction "or" and the preposition "for" shall not be used.
- h. Parentheses shall not be used to enclose any portion of the drawing title or item nomenclature.
- i. The basic name shall describe the item and not the material or method of fabrication. A basic name such as "casting," "forging," "weldment," etc., shall not be used. In lieu of such a name, a noun or noun phrase shall be assigned which indicates what the item is or what it does, for example, "BRACKET" in the item name BRACKET, SUPPORT.
- j. To insure proper item identification, a quick check is to read the assigned nomenclature backwards from the last modifier to the next modifier to the name.

Example: Cabinet, Electrical Equipment -- Fuel Transfer
Would Read
Fuel Transfer Electrical Equipment Cabinet

DRAWING AND PART IDENTIFICATION

7.1 GENERAL

All drawings and associated lists shall be identified by a code identification number and drawing number.

All end items and applicable parts thereof shall be identified by a part number.

7.2 CODE IDENTIFICATION NUMBER

The code identification number is a five-digit numerical code applicable to all activities which have produced or are currently producing items used by the Federal Government. It also applies to Government activities which control design or are responsible for the development of certain specifications, drawings, or standards which control the design of items. These numbers are assigned in conformance with Cataloging Handbook H4-1, Federal Supply Code for Manufacturers, Name to Code. Organizations which neither manufacture nor control design such as dealers, agents, or vendors of items produced by others are not included.

The code identification number assigned to KSC is 22264. The notation "CODE IDENT NO. 22264" shall be entered on the drawing or list in the appropriate block.

7.3 DRAWING NUMBER

The drawing number is assigned to a particular drawing or list for document identification purposes. Drawing numbers are assigned and controlled by the Engineering Documentation Center (EDC).



DRAWING AND PART IDENTIFICATION

7.4 ASSOCIATED LISTS**7.4.1 PARTS LIST**

When a parts list is prepared separate from the drawing, it shall be identified by the same drawing number as the assembly drawing to which it applies. In this case, the drawing number on the parts list will be prefixed by the letters "PL".

7.4.2 DATA LISTS AND INDEX LISTS

Each data list or index list shall be identified by the same drawing number as the assembly drawing to which it pertains, and the drawing number shall be prefixed by the letters "DL" for data lists and "IL" for index lists. When no assembly drawing exists, a drawing number shall be assigned to the list and shall be prefixed with the symbol "DL" or "IL" as above.

The symbols "DL", "IL", and "PL", when prefixed to the drawing number, shall not be considered part of the drawing number.

7.5 PART IDENTIFICATION

Each item, e.g., detail part, subassembly, etc., shall be identified by one part number as follows:

- a. An item covered by an approved Government agency standard and used without alteration or selection shall be identified by the proper standard number (such as, MS number for military standard and MC or KC number for NASA standard) which shall include any dash number or code necessary for complete identity.
- b. Each item, other than standard, shall be identified by one part number as required to control assembly, and stocking and replacement of interchangeable parts, subassemblies, assemblies, or end items of equipment. Part numbers for these items shall be assigned in conformance with Paragraph 7.6.
- c. When non-KSC designed items are used (such as other Government agency or vendor-designed items) without alteration or selection, they shall be identified by the original design activity's part number. The Government or vendor design activity's name and address shall be provided on the drawing to identify the item source.

NOTE: When Specification Control or Source Control Drawings are used, See Section 2, Para. 2.5.

DRAWING AND PART IDENTIFICATION

7.5 (Contd)

- d. KSC identifying numbers may be used parenthetically with standard or vendor part numbers (7.5 (a) and 7.5 (c)).

NOTE: For Item Identification Marking See Section 15, Para. 15.3.6.

- e. Standard or commercial items which are altered or selected shall be assigned an identifying part number per Paragraph 7.6. In addition, the original identification number of the part which was altered or selected and, for other than standard items, the Government or vendor design activity's name and address shall be provided on the drawing to identify the original item and source.

7.5.1 IDENTIFICATION OF RELATED PARTS

Numbers to identify special relationships between parts shall be assigned as follows:

7.5.1.1 Matched Pair Designation

Parts which must be mated and for which replacement as a matched set or pair is essential, shall be assigned a single number to designate each matched set or pair for stocking and replacement purposes. Component parts detailed on matched set drawings, in lieu of separate detail drawings, shall be individually identified by a part number as described by Paragraph 7.5 a, b, c, or e, as applicable, for material procurement and accumulation purposes.

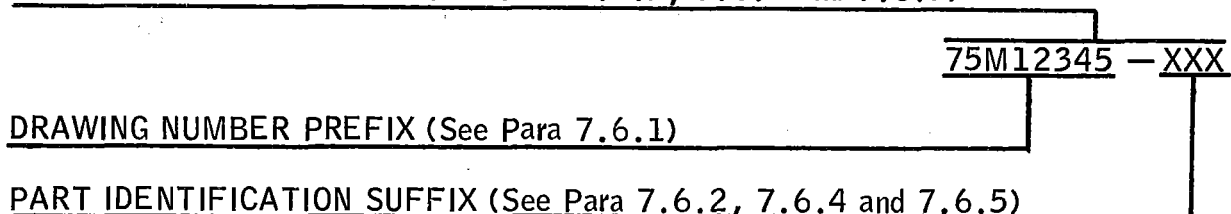
7.5.1.2 Inseparable Assembly Designation

When two or more pieces are permanently fastened together to form an inseparable assembly (such as welded, riveted, molded, etc.) the assembly shall be assigned an identifying number when required for stocking and replacement purposes. The individual pieces shall be assigned part numbers as described in Paragraph 7.5 a, b, c, or e, as applicable, when required to control assembly and/or procurement.

7.6 PART NUMBER

Part numbers shall be assigned according to the following subparagraphs and as illustrated below.

COMPLETE PART NUMBER (See Para 7.6.3, 7.6.4 and 7.6.5)





DRAWING AND PART IDENTIFICATION

7.6.1 DRAWING NUMBER PREFIX

The first portion of a complete part number shall be the drawing number (Paragraph 7.3) of the drawing for the part.

7.6.2 PART IDENTIFICATION SUFFIX USING "DASH NUMBER"

The last portion of a complete part number shall be a numeric suffix separated from the drawing number by a dash. The part identification suffix is the number assigned to the detail parts and/or assemblies shown on a particular drawing for part identification purposes. It shall be assigned in numeric sequence, for example, (-1) (-2) (-3) etc., by drafting during the preparation of the drawing.

7.6.3 COMPLETE PART NUMBER

The drawing number prefix, Paragraph 7.6.1, and the part identification suffix, Paragraph 7.6.2, together constitute the complete part number, e.g., 75M12345-1, 75M12345-125, etc. The complete part number including all numerals, letters, and dashes shall not exceed 15 characters.

CAUTION: In many cases, part numbers referenced on various documents, such as parts or material lists, EO's, etc, are prefixed with a "drawing size letter"; for example, J75M12345-1, D75M12345-1, etc. This letter is used to indicate drawing size for convenience only and has no further significance. The "drawing size letter", when prefixed to a part number, shall not be considered part of the part number.

7.6.4 PART IDENTIFICATION SUFFIX USING "BALL OUT NUMBER"

When all the details and assemblies for a particular phase of work are depicted on various sheets all identified by a single drawing number (drawing package) and parts and assemblies thereon are identified by letters and numerals, for example, A4, B6, etc., then these identifiers shall be the "PART IDENTIFICATION SUFFIX". There shall be no dash between this suffix and the drawing number. The letters "I," "O," "Q," and "X" shall not be used.

In this case the complete part number shall be written as follows: 75M12345A8, 75M12345A10, 75M12345B10, etc.

DRAWING AND PART IDENTIFICATION

7.6.5 PART IDENTIFICATION SUFFIX USING "SPECIFICATION IDENTIFICATION NUMBER"

When specifications for various components are grouped in a "specification package" and the components are identified by letters and numerals, for example, LBV4, LEM1, etc., then these identifiers shall be the "PART IDENTIFICATION SUFFIX". There shall be no dash between this suffix and the drawing number. The letters "I," "O," "Q," and "X" shall not be used.

In this case the complete part number shall be written as follows: 75M12345LBV4, 75M12345LEM1, etc.

7.7 CHANGING PART NUMBERS

Part numbers may be changed by changing the complete part number as defined in Para. 7.6.3, 7.6.4, or 7.6.5 (for examples see a, b and c below) or by changing only the part identification suffix as defined in Para. 7.6.2, 7.6.4, or 7.6.5 (for examples see d, e and f below).

Examples of changed part numbers.

Part Number of Original Version	Complete Part Number Changed to Identify a Non-interchangeable Version
a. 75M12345-1	75M22222-4
b. 75M12345A8	75M22222C5
c. 75M12345LBV4	75M22222LBV8
Part Number of Original Version	Part Identification Suffix <u>Only</u> Changed to Identify a Non- interchangeable Version
d. 75M12345-1	75M12345-5
e. 75M12345A8	75M12345B4
f. 75M12345LBV4	75M12345LBV6

The part number shall be changed, or not changed, as required by the following subparagraphs.

7.7.1 INITIATION OF PART NUMBER CHANGES

Engineering changes may be incorporated and documented (without changing part number) by drawing change letter control only, up to the cut-off date established for the incorporation of changes in hardware on the first unit of a CEI mission-design series, or component thereof, and providing that all such changes are made effective on CEI serial



DRAWING AND PART IDENTIFICATION

7.7.1 (Contd)

number one and on. Thereafter, drawing change letter control shall continue and, in addition, part numbers shall be changed, or not changed, as required by the Paragraphs 7.7.2, 7.7.3, 7.7.4, and 7.7.5 below.

NOTE

In no instance shall the cut-off date established for the incorporation of changes in hardware be later than the date the equipment is turned over to operating personnel as operationally ready.

7.7.2 CHANGES REQUIRING PART RE-IDENTIFICATION

The part number for an end item or subassembly, component or part thereof, shall be changed whenever one or more of the following non-interchangeable conditions exist:

- a. Performance or durability is affected to such an extent that superseded items must be discarded for reasons of safety, malfunctioning, or reliability.
- b. Parts, components, subassemblies, or complete end items are changed to such an extent that the superseded and superseding items are not directly and completely interchangeable with respect to installation and specified performance.
- c. When superseded parts, components, subassemblies, or end items are limited for use in specific units of an end item and the superseding parts, components, subassemblies, or end items are not so limited to use.
- d. When a part, component, subassembly, or end item, which has been identified and documented by a design activity other than KSC, is altered or selected, a new part number shall be assigned to the altered or selected item (see Paragraph 7.5 (e)).
- e. When a material, process, or protective treatment is changed to such an extent that any of the conditions in a, b, or c exist.
- f. When a physical part, component, sub-assembly, or end item is reworked in production or retrofit by a kit into a later part number version of the item, and is completely interchangeable with all items identified by the later part number, the physical part shall be re-identified to the part number of the later version.

DRAWING AND PART IDENTIFICATION

7.7.3 CHANGING AN ITEM INTO A STANDARD PART

A part or component may be established as a standard and identified by a standard specification identification number when all of the following apply:

- a. The part or component has a multiple usage and is expected to have a design application in more than one end item.
- b. The part or component is nonrepairable (throw-away) and will not be provisioned below the level identified by the standard specification identification number.
- c. The part or component is completely specified in a specification document with respect to performance, durability, reliability, form, fit, qualification, and inspection requirements.
- d. One or more alternate sources is approved and qualified to supply the item.

A part or component may be established as a KC standard upon the approval of a request from a design group to the Document Control Board. The request should be accompanied by a submittal of sufficient information to verify that all of the conditions in a,b,c, and d apply.

7.7.4 CHANGES IN HIGHER LEVEL ASSEMBLY PART NUMBERS

When an end item contains a noninterchangeable item, the part number of the noninterchangeable item, of its next assembly, and of all progressively higher assemblies shall be changed only up to and including the assembly where interchangeability is reestablished. Part numbers shall not be changed above this level of assembly for any reason.

7.7.5 CHANGES NOT REQUIRING PART RE-IDENTIFICATION

The part number shall not be changed when:

- a. A new usage is found for an existing part.
- b. None of the conditions in Paragraph 7.7.2 occur.
- c. A commercial, vendor, subcontractor, or Government-furnished item is used (or new usage is found for the item) without alteration or selection.



SURFACE ROUGHNESS

8.1 GENERAL

Surface roughness symbols shall conform to USAS B46.1-62 for all drawings prepared for KSC.

8.1.1 APPLICATION

Unless otherwise specified, the finish symbol (\sqrt{XX}) indicates the maximum allowable surface roughness produced by a machining operation.

When surface is produced by other methods such as casting, forging, punching, molding etc., the method will be indicated by a note adjacent to the symbol, such as $250\sqrt{AS\ CAST}$, $125\sqrt{AS\ PUNCHED}$, etc.

A finish symbol (\sqrt{XX}) with the roughness value shown on a part produced by casting, forging, etc., shall indicate an allowance for machine finish on the surface so indicated.

In general, the finish symbol (\sqrt{XX}) shall be shown only on the view where the controlling dimension is located and omitted from all other views. However, when a machined surface appears in several views on a large drawing (E size), the finish symbol without the roughness value ($\sqrt{}$) may be shown in the different views or sections.

When using multiple sheet drawings, the finish symbol (\sqrt{XX}) is placed near the controlling dimension and the symbol ($\sqrt{}$) without the roughness value must be placed on all the machined surfaces shown on each sheet.

When all or the majority of machined surfaces of a part machined all over are to be the same roughness, the delineation should specify only the exception and a note " \sqrt{XX} unless otherwise specified" should be used to specify the finish required on the majority of finish surfaces.

8.2 RELATIVE COST

Manufacturing costs are affected by tolerances and surface roughness.

Relative costs of tolerances and finishes are difficult to establish as a fixed relationship, due to the many variables such as size, method of producing, materials, etc.; however, it is noted that production costs increase rapidly as surfaces become smoother and tolerances become tighter. Therefore, the selection of the proper degree of surface roughness and the use of the largest tolerances acceptable, dependent upon

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SURFACE ROUGHNESS

8.2 (Cont'd)

size, function of the item, operating conditions etc., should be considered at all times as important factors in preventing excessive costs.

Figure 8.2-1 shows the approximate relative costs of surface roughness with some typical methods of producing the surfaces.

REVISED _____

SURFACE ROUGHNESS

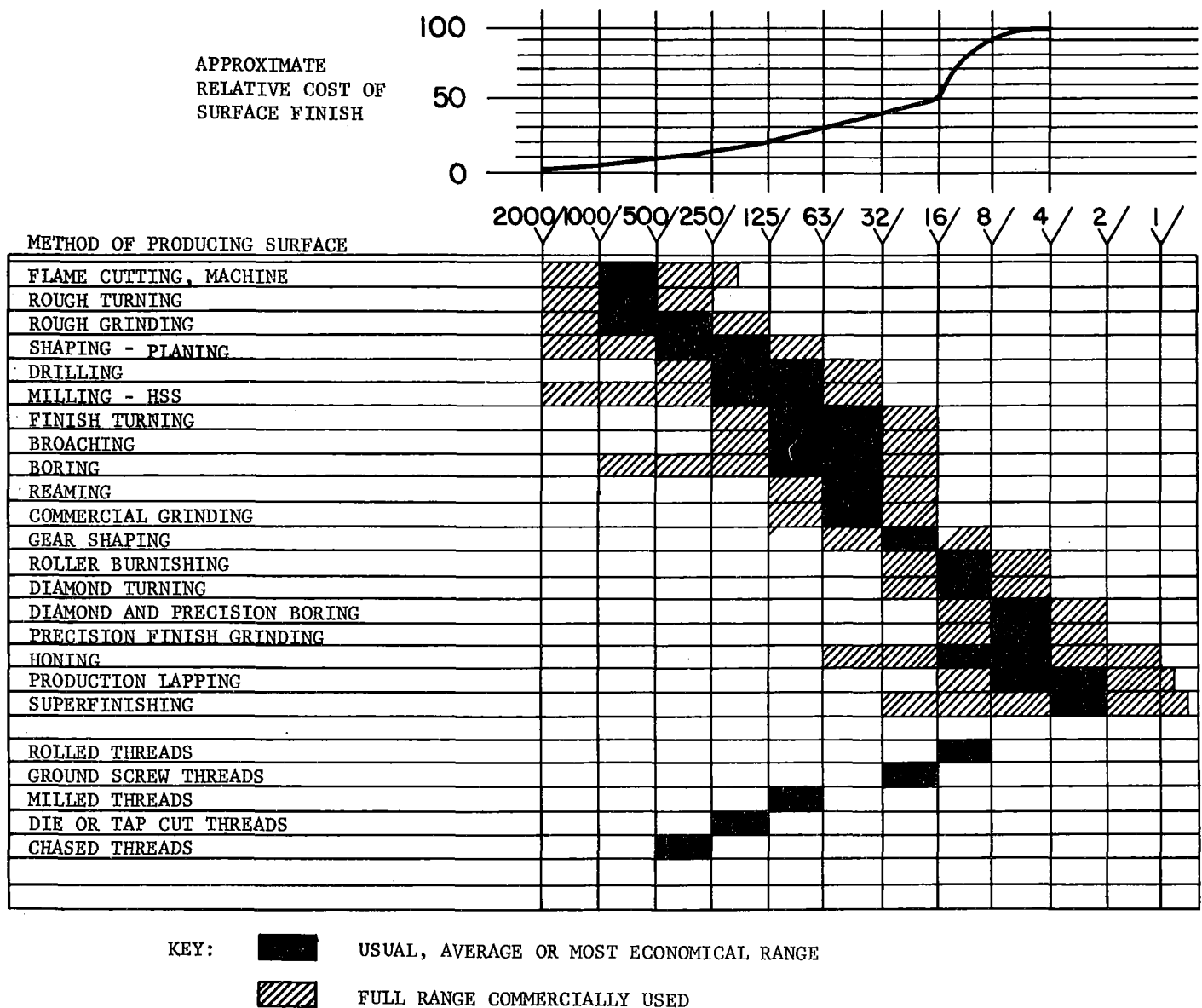


Figure 8.2-1. Relative costs and typical methods of Producing Surface Finishes

DRAWING NOTES

9.1 GENERAL

This section contains guidelines for the generation and use of notes and brief descriptions of various conditions, with suggested drawing notes for stating instructions and/or requirements.

NOTE

The standards and specifications included in the listed notes merely suggest a method or process and are not meant to be mandatory. The responsible engineer shall determine the standard or specification best suited for specific design requirements.

9.2 GENERATION OF NOTES

The following are included for use as guidelines when generating drawing notes.

- a. Drawing notes should be clear and specific in wording to avoid misinterpretation.
- b. Common shop trade terms and words should be used to the extent practicable.
- c. Notes should be as brief and concise as possible.
- d. In general, notes should not be underscored; however, to facilitate manual search it may be desirable to underscore references to documents which must be included in a data list.
- e. Notes which are repeated on similar or related drawings should be identical in wording.
- f. Notes should not duplicate information recorded elsewhere on the drawing.
- g. References to individuals should be avoided; if unavoidable, use individual's position title rather than his name.



DRAWING NOTES

9.2 (Contd)

- h. Notes should not include references to specific manufacturing or machining methods or references to intermediate steps in the production process (such as roughing operations, with dimensions and limits pertaining thereto). An exception to this rule is acceptable in the unusual cases in which the only known method of stating requirements or ensuring the attainment of such requirements is by specifying intermediate steps or processes (e.g. dimensions before and after plating).
- i. When exceptions to a general drawing note are specified in the field of the drawing, the phrase "unless otherwise specified" should be used in conjunction with the general note.

9.3 DRAWING NOTES**9.3.1 INDEX****Castings (paragraph 9.3.1.1)**

N1	Surface Finish
N2	Machining Allowance
N3	Maximum Draft
N4	Cast Corners
N5	Cast Fillets
N6	Cast Walls
N7	Tolerance, Cast Angles
N8	Tolerance, Casting Linear Dimensions
N9	Tolerance, Casting Linear Dimensions
N10	When only Tooling Points are used
N11	When Tooling and Tooling Locations are used

Electrical and Electronic (paragraph 9.3.1.2)

N1	Fabrication
N2	Wiring Diagram Reference
N3	Schematic Reference
N4	Wiring Harness Reference
N5	Schematic Note
N6	Reference Designation Marking
N7	Partial Reference Designation

DRAWING NOTES

9.3.1 (Contd)

Finishes, Applied (paragraph 9.3.1.3)

N1	Anodic Finish (Sulphuric Acid)
N2	Anodic Finish (Chromic Acid)
N3	Anodic Finish Dyed (Sulphuric Acid)
N4	Anodic Finish Dyed (Chromic Acid)
N5	Anodic - Hard Coat (Alumilite or Martin)
N6	Chemical Film for Aluminum
N7	Cadmium Plating
N8	Cadmium Plating
N9	Chromium Plating
N10	Chromium Plating
N11	Dichromate Treatment
N12	Nickel Plating
N13	Nickel Plating
N14	Passivating Corrosion Resistant Steel
N15	Phosphate Coating
N16	Phosphate Coating
N18	Painting of Steel Structures
N19	Painting of Steel Cabinets and Panels
N20	Painting of Aluminum
N21	Clear Varnish
N22	Touch-Up Finish
N23	Touch-Up Finish
N24	Dissimilar Metal Protection
N25	Grease Coating

Finishes, Machined (paragraph 9.3.1.4)

N1	Sharp Edges
N2	Surface Finish

Forgings (paragraph 9.3.1.5)

N1	Surface Finish
N2	Machining Allowance
N3	Maximum Draft



DRAWING NOTES

9.3.1 (Contd)

- | | |
|-----|--|
| N4 | Forged Corners |
| N5 | Forged Fillets |
| N6 | Forged Walls |
| N7 | Tolerance, Forged Angles |
| N8 | Tolerance, Forging Linear Dimensions |
| N9 | Tolerance, Forged Linear Dimensions |
| N10 | When only Tooling Points are used |
| N11 | When Tooling Points and Tooling Locations are used |

Heat Treatment (paragraph 9.3.1.6)

- | | |
|----|---------------------|
| N1 | Heat Treatment |
| N2 | Case Hardening |
| N3 | Induction Hardening |

Inspection (paragraph 9.3.1.7)

- | | |
|----|----------------------------------|
| N1 | Magnetic Particle Inspection |
| N2 | Non-Magnetic Particle Inspection |
| N3 | Ultrasonic Inspection |

Riveting (paragraph 9.3.1.8)

- | | |
|----|-----------------|
| N1 | Rivet Coding |
| N2 | Riveting |
| N3 | Blind Fasteners |

Threads and Threaded Fasteners (paragraph 9.3.1.9)

- | | |
|----|---|
| N1 | Helical Coil Inserts |
| N2 | Helical Coil Inserts |
| N3 | Screw Threads (Am-Nat) |
| N4 | Torquing Requirements |
| N5 | Locking Requirements - Flat Head Screws |
| N6 | Safety Wiring |
| N7 | Pipe Threads (Taper) |

DRAWING NOTES

9.3.1 (Contd)

Miscellaneous (paragraph 9.3.1.10)

- | | |
|----|-----------------------------------|
| N1 | Drawing Terms and Tolerances |
| N2 | Inactive Drawings |
| N3 | Liquid Locking Compound |
| N4 | Cleaning of Metals Before Welding |

9.3.1.1 Castings

DESCRIPTION	DRAWING NOTE
<u>Surface Finish</u>	Unless otherwise specified, all cast surfaces ✓ N1
<u>Machining Allowance</u>	Material for machining shall be provided on surfaces indicated by finish symbol (✓) except when the finish symbol is qualified by the words "as cast." N2
<u>Maximum Draft</u>	Maximum draft of (*) degree (s) will be permitted provided it does not decrease the section below tolerance. N3
<u>Cast Corners</u>	Unless otherwise specified, all cast external corners to have (*) radius maximum. N4
<u>Cast Fillets</u>	Unless otherwise specified, all cast fillets to have (*) radius. N5
<u>Cast Walls</u>	Unless otherwise specified, all cast walls to be (*) thick. N6
<u>Tolerance, Cast Angles</u>	Unless otherwise specified, all cast angles to be \pm (*) degree(s). N7



DRAWING NOTES

9.3.1.1 (Contd)

DESCRIPTION	DRAWING NOTE
<u>Tolerance, Casting Linear Dimensions</u> (For combined machining and casting drawings where superimposed dimensions are shown)	Unless otherwise specified, the tolerance on casting dimensions shall be $\pm (*)$ in./in. or $\pm (*)$, whichever is greater. Where a machining dimension also defines a casting dimension, the above tolerance applies to the mean dimension. On an unspecified dimension between two cast features, the above tolerance applies to the calculated mean dimension. <div>N8</div>
<u>Tolerance, Casting Linear Dimensions</u> (For separate raw casting drawings)	Unless otherwise specified, the tolerance on casting dimensions shall be $\pm (*)$ in./in. or $\pm (*)$, whichever is greater. On an unspecified dimension between two cast features, the above tolerance applies to the calculated mean dimension. <div>N9</div>
<u>When only Tooling Points are used</u>	Tooling points identified by $\frac{T P}{1 A}, \frac{T P}{2 A}$, etc., are the planned points on surfaces from which all other points or surfaces are to be checked and machining operations started. <div>N10</div>
<u>When Tooling Points and Tooling Locations are used</u>	Tooling points and tooling locations identified by $\frac{T P}{1 A}, \frac{T L}{4 A}$, etc., are the planned points on surfaces from which all other points or surfaces are to be checked and machining operations started. <div>N11</div>
(*) as required by design	



DRAWING NOTES

9.3.1.2 Electrical and Electronic

DESCRIPTION	DRAWING NOTE
<u>Fabrication</u>	Unless otherwise specified, fabrication of electrical ground support equipment shall be in accordance with KSC-E-165. N1
<u>Wiring Diagram Reference</u> (referenced on schematics and assembly drawings)	For Wiring Diagram see Drawing _____ N2
<u>Schematic Reference</u> (referenced on wiring diagrams and assembly drawings)	For Schematic Diagram see Drawing _____ N3
<u>Wiring Harness Reference</u> (referenced on wiring diagram)	For Wiring Harness see Drawing _____ N4
<u>Schematic Note</u> (used on schematics instead of repeating the symbols Ω and UF)	Unless otherwise specified, resistance is in ohms; capacitance is in microfarads. N5
<u>Reference Designation Marking</u> (for use on electrical assemblies requiring reference designation marking)	Mark Reference Designation approximately where shown per KSC-STD-E-0015. N6
<u>Partial Reference Designation</u> (for use when partial reference designations are shown on diagrams and electrical assemblies)	Partial Reference Designation is shown; for complete designation prefix with unit number and assembly designation(s). N7



DRAWING NOTE

9.3.1.3 Finishes, Applied

DESCRIPTION	DRAWING NOTE
<u>Anodic Finish (Sulphuric Acid)</u> For maximum resistance to abrasion on aluminum alloys where dimensional tolerances are $\pm .003$ or more. Do not use for fabricated spot welded or riveted assemblies and parts with non-aluminum cast inserts.	Finish anodic (sulphuric acid) per 7.2.1 of MIL-STD-171 all over, except anodic may be omitted from tapped holes. N1
<u>Anodic Finish (Chromic Acid)</u> For aluminum alloy parts with dimensional tolerances less than $\pm .003$. This finish may be used for fabricated spot welded or riveted assemblies. Do not use for parts with non-aluminum cast inserts. This finish shall not be applied to alloys with nominal copper content in excess of 5.0% or when the total content of the alloying elements exceed 7.5%.	Finish anodic (chromic acid) per 7.1.1 of MIL-STD-171 all over, except anodic may be omitted from tapped holes. N2
<u>Anodic Finish Dyed (Sulphuric Acid)</u> For maximum resistance to abrasion on aluminum alloys where dimensional tolerances are $\pm .003$ or more. Do not use for fabricated spot welded or riveted assemblies and parts with non-aluminum cast inserts.	Finish anodic (sulphuric acid) per 7.2.2 of MIL-STD-171 dyed _____* all over, except anodic may be omitted from tapped holes. N3 *Specify color.
<u>Anodic Finish Dyed (Chromic Acid)</u> For aluminum alloy parts with dimensional tolerances of less than $\pm .003$. This finish may be used for fabricated spot welded or riveted assemblies. Do not use for parts with non-aluminum cast inserts. This finish shall not be applied	Finish anodic (chromic acid) per 7.1.2 of MIL-STD-171 dyed _____* all over, except anodic may be omitted from the tapped holes. N4

DRAWING NOTES

9.3.1.3 (Contd)

to alloys with nominal copper content in excess of 5.0% or when the total content of the alloying elements exceed 7.5%.	*Specify color.	N4 (Contd)
DESCRIPTION	DRAWING NOTE	
<p><u>Anodic - Hard Coat</u></p> <p>For extreme wear and maximum abraision resistance and for special heat transfer applications on aluminum alloys. Use chromic acid for non-hard-coated surfaces; such as aluminum alloys 1100, 3003, 5052, 6061, 6151, and 7075; and cast aluminum alloys # 43, 355, and 356.</p> <p>The following conditions apply to this finish.</p> <ol style="list-style-type: none"> 1. All threads must be masked. 2. Non-aluminum inserts are not permitted. 3. Hard coatings may vary in thickness from .0005 to more than .004 and unless specified shall be nominal .002 ±.0005. (penetrates .001) 4. Critical surfaces must show the dimension before and after coating when tolerances closer than + .0005 are required. Hardened surfaces are usually ground or lapped. 5. Not satisfactory on aluminum alloys having more than 5% silicon or more than 7% combined total of copper and silicon. 	<p>Finish hard coat per 7.5 of MIL-STD-171, except as noted.</p> <p>(Drawing must indicate surfaces that are not to be coated.)</p>	N5



DRAWING NOTES

9.3.1.3 (Contd)

<p>6. Drawings must indicate surface where hardness is required to facilitate selection of control surface.</p> <p>7. Coating is nonconductive when dry. Breakdown voltage is approximately 1500 V. Due to inherent crazing of the hard coat, moisture causes a severe electrical breakdown of the coat, reducing electrical resistance to nil.</p>		N5 (Contd)
DESCRIPTION	DRAWING NOTE	
<p><u>Chemical Film for Aluminum</u></p> <p>General use for aluminum and aluminum alloys in lieu of anodizing. These chemical films are recommended in preference to anodizing for general protection of aluminum parts which will be painted or for parts which are unpainted but sheltered within other equipment (e.g. unpainted parts inside a nose cone structure). Exposed unpainted aluminum parts will generally be anodized for better abrasion and corrosion protection.</p> <p>(a) Use this note where subsequent paint finish is not required. (b) Use this note for use under paint. (c) Use this note where low electrical resistance is necessary and where subsequent paint finish is not required.</p>	<p>(a) Finish 7.3.1 of MIL-STD-171</p> <p>(b) Finish 7.3.2 of MIL-STD-171</p> <p>(c) Finish 7.3.3 of MIL-STD-171</p>	N6
<p><u>Cadmium Plating</u></p> <p>General use for steel parts except springs and parts having hardness greater than 35 Rockwell C.</p>	<p>Finish cadmium plate per ____* of MIL-STD-171.</p>	N7



DRAWING NOTES

9.3.1.3 (Contd)

Finish Number 1.1.2.2 - General use .0003 thick. 1.1.2.3 - Threaded parts .0002 thick. Drawing must specify finish number.	*Specify finish number.	N7 (Contd)
DESCRIPTION	DRAWING NOTE	
<u>Cadmium Plating</u> General use for springs and parts having hardness greater than 35 Rockwell C. Thickness .0002 minimum with chromate treatment.	Finish cadmium plate per 1.1.2.3 of MIL-STD-171. Treat to stress relieve and prevent hydrogen embrittlement within one hour after plating.	N8
<u>Chromium Plating</u> For wear resistance on ferrous alloys. Minimum Thickness .002. Drawing note must specify thickness required. NOTE Critical flat surfaces require a radius to prevent buildup at edges. The size of the radius must be determined by trial.	Finish chromium plate ____ thick per 1.2.2 of MIL-STD-171.	N9
<u>Chromium Plating</u> For wear resistance on ferrous alloy springs and parts having a hardness greater than 35 Rockwell C. Minimum thickness .002. Drawing note must specify thickness required. NOTE Critical flat surfaces require a radius on edges to prevent buildup. The size of radius required must be determined by trial.	Finish chromium plate ____ thick per 1.2.2 of MIL-STD-171. Treat to stress relieve and prevent hydrogen embrittlement within one hour after plating.	N10
<u>Dichromate Treatment</u> (For magnesium alloys) NOTE Cast inserts if/when used must be cadmium plated.	Finish 8.4 of MIL-STD-171.	N11



DRAWING NOTES

9.3.1.3 (Contd)

DESCRIPTION	DRAWING NOTE
<u>Nickel Plating</u> (For decorative plating on ferrous alloys)	Finish nickel plate per 1.4.1.4 of MIL-STD-171 N12
<u>Nickel Plating</u> (For decorative plating on copper-base alloys)	Finish nickel plate per 1.4.1.6 of MIL-STD-171. N13
<u>Passivating Corrosion Resistant Steel</u> For all types of corrosion resistant steel containing 12% or greater chromium. Individual machine parts and parts fabricated by continuous sealing welds are passivated after finish machining. Parts fabricated by spot or intermittent welding, silver or copper brazing, or riveting are passivated separately before fabrication.	Finish 5.4.1 of MIL-STD-171. N14
<u>PHOSPHATE COATING</u> Use for coating ferrous alloys other than stainless steel with either a manganese or zinc base phosphate. Dimensions apply prior to phosphate coating. Use note N15 for parts under 39 Rockwell C. Use note N16 for parts 39 Rockwell C and over.	<div> Finish 5.3.1.2 or 5.3.2.2 of MIL-STD-171. N15 </div> <div> Finish 5.3.1.2 or 5.3.2.2 of MIL-STD-171 except in Table 1 or MIL-P-16232 the treatment for relief of hydrogen embrittlement shall be one (1) hour minimum. N16 </div>



DRAWING NOTES

9.3.1.3 (Contd)

DESCRIPTION	DRAWING NOTE
<u>Painting of Steel Structures</u> Clean per 4.1, and paint per 22.2 (gloss); drawing must specify color and color number.	Finish No. 4.1 + 22.2 of MIL-STD-171____, Color No. ____ of FED-STD-595. N18
<u>Painting of Steel Cabinets and Panels</u> Clean per 4.1, phosphate per 5.2, and paint per 21.9 (semigloss). Drawing must specify color and color number.	Finish No. 4.1 + 5.2 + 21.9 of MIL-STD-171____, Color No. ____ of FED-STD-595. N19
<u>Painting of Aluminum.</u> Clean per 4.1. Specify 7.1.1 anodic (perferred) TT-P-666 or 7.3 chemical film. Paint per 21.9 (semigloss) except use TT-P-666 primer. Drawing must specify treatment, color, and color number.	Finish No. 4.3 + ____ + 21.9 (except use TT-P-666 primer) of MIL-STD-171____. Color No. ____ of FED-STD-595. N20

 DRAWING NOTES

9.3.1.3 (Contd)

DESCRIPTION	DRAWING NOTE
<u>Clear Varnish</u> For cut edges of non-metallic and insulation materials, including molded parts	Apply clear varnish per MIL-V-173 to all cut surfaces. N21
<u>Touch-Up Finish</u> For unprotected metallic surfaces and damaged finishes. This note should be specified on assembly drawings, where applicable.	After assembly, touch up all exposed unprotected surfaces with an approved finish to match the surrounding surface. N22
<u>Touch-Up Finish</u> For unprotected metallic surfaces, damaged finishes, and external hardware, such as screw and bolt heads, with touch-up paint to match.	After final assembly, unless otherwise specified, all exposed unprotected surfaces and unpainted hardware shall be painted with an approved touch-up paint to match the surrounding surface. N23
<u>Dissimilar Metal Protection</u> To be used for protection against deterioration between dissimilar metals. One of the following types shall be specified: Type I - Protection for use under severe deteriorating conditions. Type II - Protection for use under moderately severe deteriorating conditions. Type III - Protection for use under mild deteriorating conditions.	Dissimilar metal protection per MIL-F-7179, Type <u>(*)</u> . N24 (*) Specify type I, II, or III.

DRAWING NOTES

9.3.1.3 (Contd)

DESCRIPTION	DRAWING NOTE
<u>Grease Coating</u> Use for rabbet-fitted parts in aluminum or magnesium alloys where adjustments may be made. For unprotected metallic surfaces such as gear teeth and other surfaces where corrosion protection is not provided. This note should be specified on assembly drawings, where applicable.	(*) shall be coated with grease per MIL-G-23827. N25 (*) Specify surface, area, etc., to be coated.

9.3.1.4 Finishes, Machined

DESCRIPTION	DRAWING NOTE
<u>Sharp Edges</u>	Remove burrs and break sharp edges. N1
<u>Surface Finish</u> Use when the majority of machined surfaces have the same surface finish.	Unless otherwise specified, all machined surfaces $\sqrt{\text{X}}$. N2 *Microinches

9.3.1.5 Forgings

DESCRIPTION	DRAWING NOTE
<u>Surface Finish</u>	Unless otherwise specified all forged surfaces $\sqrt{\text{X}}$. N1
<u>Machining Allowance</u>	Material for machining shall be provided on surfaces indicated by finish symbol ($\sqrt{\text{X}}$) except when the finish symbol is qualified by the words "as forged." N2



DRAWING NOTES

9.3.1.5 (Contd)

DESCRIPTION	DRAWING NOTE
<u>Maximum Draft</u>	Unless otherwise specified, maximum draft of (*) degree(s) will be permitted provided it does not decrease the section below tolerance. N3
<u>Forged Corners</u>	Unless otherwise specified, all forged external corners to have (*) radius maximum. N4
<u>Forged Fillets</u>	Unless otherwise specified, all forged fillets to have (*) radius. N5
<u>Forged Walls</u>	Unless otherwise specified, all forged walls to be (*) thick. N6
<u>Tolerance, Forged Angles</u>	Unless otherwise specified, all forged angles to be \pm (*) degree(s). N7
<u>Tolerance, Forging Linear Dimensions</u> (For combined machining and forging drawings where superimposed dimensions are shown)	Unless otherwise specified, the tolerance on forging dimensions shall be $+(*) - (*)$ in./in. or $+(*) - (*)$, whichever is greater. Where a machining dimension also defines a forging dimension, the above tolerance applies to the mean dimension. On an unspecified dimension between two forged features, the above tolerance applies to the calculated mean dimension. N8
<u>Tolerance, Forging Linear Dimensions</u> (For separate raw forging drawings)	Unless otherwise specified, the tolerance on forging dimensions shall be $+(*) - (*)$ in./in. or $+(*) - (*)$, whichever is greater. On an unspecified dimension between two forged features, the above tolerance applies to the calculated mean dimension. N9
<u>When Only Tooling Points are used</u>	Tooling points identified by $\begin{array}{c} T P \\ 1 A, 2 A, \text{ etc.}, \end{array}$ are the planned points on surfaces from which all other points or surfaces are to be checked and machining operations started. N10

DRAWING NOTES

9.3.1.5 (Contd)

DESCRIPTION	DRAWING NOTE
<u>When Tooling Points and Tooling Locations are used</u> (*) As required by design	Tooling points and tooling locations N11 <div style="text-align: center;"> $\frac{T}{P}$ $\frac{T}{L}$ </div> identified by 1A, 4B, etc, are the planned points on surfaces from which all other points or surfaces are to be checked and machining operations started.

9.3.1.6 Heat Treatment

DESCRIPTION	DRAWING NOTE
<u>Heat Treatment</u> Furnace-type heat treatment on through-hardenable alloys will be referenced to stress range. Note that recommended ranges start at 120,000 psi and go to 220,000 psi in increments of 20,000 psi.	Heat treat to _____ to _____ psi N1 tensile strength per MIL-H-6875.
<u>Case Hardening</u> For low carbon steel. 88-92 Rockwell 15-N scale, .010 - .015 deep. 73-83 Rockwell 30-N scale, .020 -.035 deep. 55-66 Rockwell C scale, .040 - .070 deep.	Case harden to _____ Rockwell " " N2 from _____ to _____ deep.
<u>Induction Hardening</u> For alloy steel when hardening is required on a special surface. The drawing must specify such surface(s).	Induction harden surface _____ to _____ N3 Rockwell "C" for depth of _____ to _____ on finished part.



DRAWING NOTES

9.3.1.7 Inspection

DESCRIPTION	DRAWING NOTE
<u>Magnetic Particle Inspection</u> To detect surface cracks, specify on detail drawings as follows: for parts heat-treated to 35 Rockwell C and above: May also be used for magnetic castings and forgings when requested.	Part must have magnetic particle inspection per MIL-I-6868. N1
<u>Non-Magnetic Particle Inspection</u> To detect surface cracks, specify on detail drawings, as applicable. Use for parts heat-treated to 35 Rockwell C and above. Use for particle inspection of non-magnetic stainless steel (300 series).	Part must have penetrant inspection in accordance with MIL-I-6866 type 1. N2
<u>Ultrasonic Inspection</u> To detect internal defects, specify in detail drawings, as applicable.	Part must have ultrasonic inspection, in accordance with MIL-STD-271. N3

9.3.1.8 Riveting

DESCRIPTION	DRAWING NOTE
<u>Riveting Coding</u> (For use when rivet coding is required)	Rivet coding per NAS523. N1
<u>Riveting</u> (*) MSFC-STD -156 A10509301 or Other	Rivet per ____ (*). N2



DRAWING NOTES

9.3.1.8 (Contd)

DESCRIPTION	DRAWING NOTE
<u>Blind Fasteners</u> Used for the installation and inspection of high strength pull-type fasteners.	Install fasteners per MIL-F-81177. N3

9.3.1.9 Threads and Threaded Fasteners

DESCRIPTION	DRAWING NOTE
<u>Helical Coil Inserts</u> (For use on drawings requiring tapping for, and installation of, inserts)	Tap and install inserts per MS 33646. N1
<u>Helical Coil Inserts</u> For use on drawings requiring tapping for, and installation of, inserts and removal of notched tangs when screw must project through the insert.	Tap and install inserts per MS 33646 N2 and remove notched tangs after installation.
<u>Screw Threads</u>	Screw threads shall be per * N3 *Use MIL-S-7742 until 31 Dec. 1969 Use MIL-S-8879 after 31 Dec. 1969
<u>Torquing Requirements</u>	Torque to _____ inch pounds. N4
<u>Locking Requirements - Flat Head Screws</u> (For locking flat head screws, sizes #10 and smaller, using an adhesive)	Lock flat head screws in accordance with MIL-S-22473, grade _____. N5
<u>Safety Wiring</u> (For use on assembly drawings requiring safety wiring)	Safety wire all drilled head screws, bolts, etc., after assembly per MS 33540. N6



DRAWING NOTES

9.3.1.9 (Contd)

DESCRIPTION	DRAWING NOTE
<u>Pipe Threads (Taper)</u>	Tapered pipe threads to be per MIL-P-7105 N7

9.3.1.10 Miscellaneous

DESCRIPTION	DRAWING NOTE
<u>Drawing Terms and Tolerances</u> For use on most detail and assembly drawings where machining is required. Do not use on vendor control-type drawings (e.g. spec. control, source control, etc.)	Drawing terms and tolerances per KSC-STD-168 N1
<u>Inactive Drawings</u> This note is for drawings which have become inactive. The note should be placed over, or adjacent to, the drawing title block using approximately 1/4-inch high letters.	Inactive for new design N2
<u>Liquid Locking Compounds</u> For threaded parts on closely fitted metal surfaces. For design and usage data see MS18069 and MIL-S-22473, paragraph 6.1.	Apply primer and sealing compound to (*) _____ per MIL-S-22473, Grade (**). N3 (*) Specify surface, part, etc. (**) Specify Grade.
<u>Cleaning of Metals before Welding</u>	Clean component parts per MIL-S-5002 immediately before welding. N4

DRAWING REVISIONS

10.1 GENERAL

This section defines the requirements for revising engineering drawings and provides a uniform method of identifying and recording revisions on the drawings.

10.1.1 DEFINITION OF A DRAWING REVISION

The term "REVISION" refers to any changes made to add, change, or delete information on a drawing after the drawing has been released.

10.2 REQUIREMENTS TO REVISE DRAWINGS

A drawing shall be revised in accordance with instructions from the KSC Project Engineer responsible for the integrity of the drawing, or in accordance with a released Engineering Order (EO) approved by him.

10.3 INTERCHANGEABILITY

No change shall be made to any part or group which affects mechanical or electrical interchangeability. Changes in design which affect interchangeability require new parts or groups, (maintaining superseded parts for renewal purposes) except for:

- a. Detail parts which are permanently connected together to form an assembly by some such process as welding. The assembly shall be interchangeable.
- b. Detail parts or assemblies which are considered impractical to supply as renewal parts. A note may be added to the assembly drawing stating that such parts cannot be furnished separately.
- c. Parts requiring fitting at assembly, provided this fitting is covered by a note on the assembly drawing.

10.4 REVISION IDENTIFICATION

Revisions to drawings are recorded in the "REVISION BLOCK" (see Paragraph 10.5) and shall be identified by the use of revision letter symbols, change suffix numbers, and zone identification.

DRAWING REVISIONS

10.4.1 REVISION LETTER SYMBOLS

Revision letter symbols shall be upper case starting with "A" and advancing in alphabetical sequence each time the drawing is revised. The letters "I", "O", "Q", and "X" shall not be used. When revisions are numerous enough to exhaust the alphabet, the revisions following the letter "Z" shall be lettered "AA", the next "AB" etc.; the next sequence shall be "BA", "BB", etc.

10.4.2 CHANGE SUFFIX NUMBERS

A suffix number, in parentheses, shall start with "(1)" and advance in numerical sequence to identify each change incorporated for each REVISION LETTER SYMBOL.


10.4.3 ZONE IDENTIFICATION

Revisions made in the field of the drawing on a zoned format shall be identified by a zone location with the letter preceding the numeral, H-2, H-3, A-1, B-3, etc.

10.4.3.1 Revision Symbol

Revisions which cannot be properly described and located by the written data in the description column may require the use of a revision symbol to indicate the location of the changes in the field of the drawing. Revision symbols shall not be used on loft or undimensioned drawings, nor on schematics, diagrams, etc., when their use might jeopardize drawing clarity.

- a. Revision symbol shall be a revision letter and change suffix number enclosed in a 3/8 inch diameter circle.

Revision letter symbol  Change suffix number

- b. Each individual change shall be identified by a separate revision symbol except when a revision is made in the title block, list of materials, numbered notes and diagrams. When numerous changes are made in one area so that individual revision symbols would crowd the drawing, a single revision symbol may be used to identify the group of changes if they can be properly described and located by the written data in the description column.
- c. Revision symbols shall be located as near as practical to the area of change and when impractical to do so, leader lines may be used following standard drafting practices.

DRAWING REVISIONS

10.5 REVISION BLOCK RECORDING

Each revision shall be identified in accordance with Paragraph 10.4 and recorded in the revision block at the time the drawing is changed.

10.5.1 REQUIREMENTS

- a. Zones, identified in accordance with Paragraph 10.4.3, in which changes are made shall be noted in the "Zone" column. Where more than one change description is written on a line the zone identification may be entered in the "DESCRIPTION" column (see Figure 10.5-1).
- b. Revision letter symbols, in accordance with Paragraph 10.4.1, identifying each drawing revision shall be noted in the "SYM" column.
- c. A change shall be noted in the "DESCRIPTION" column with its appropriate suffix number and a brief description for each individual revision made (see Paragraph 10.4.2). When it is desired to document a change that is too extensive to be noted in the DESCRIPTION column, the notation "General Change in---(give a brief description of the change)---see EO----" may be entered, and an EO describing the change in detail released with the revised drawing. See Figure 10.5-1.
- d. The use of abbreviations may be used in accordance with Section 13.
- e. Pictorial sketches and symbology shall not be used.
- f. Lettering shall be neat, legible, and 1/8 inch high.

10.5.1.1 Revision Approval

The initials of the person checking and/or approving the revision shall appear in the "APPROVED" column. The date that the signatures are entered shall appear in the "DATE" column in accordance with Figure 10.5-1. Signatures, initials, and dates shall be entered in reproducible ink.

10.5.2 REVISIONS SPECIFIED BY EOs

The field of the drawing shall be revised in accordance with items described on the EO. The EO number and itemized changes shall be recorded in the "DESCRIPTION" column. More than one EO may be incorporated under the same revision letter symbol (see Figure 10.5-1, Rev. C).

KSC



MANUAL

Ground Support Equipment

DRAWING REVISIONS

REVISIONS				
ZONE	SYM	DESCRIPTION	DATE	APPROVAL
B-5 A-7 D-6	A	(1) GENERAL CHANGE - SEE E0 1-XXXXXXXX	Feb 4 1964	F. Smith KOL. PRS
D-4	B	(1) WAS 1.75 (ZONE H-6)(2) ADDED PT 5 & TAPPED HOLES (ZONE C-4) (3) DELETED NOTES AT PART 2 E0 2-XXXXXXXX	Mar 10 1964	F. Smith KOL
B-6	C	(1) MATL WAS QQ-S-633 E0 3-XXXXXXXX (2) ADDED C6 E0 4-XXXXXXXX REVISED SHEET 2	May 19 1964	K. Jones CDK.
E-6 B-9	D	(1) .030 WAS .020 (2) 4.70 WAS 4.56 E0 5-XXXXXXXX (3) ADDED PART 5 REVISED SH 3 E0 6-XXXXXXXX	July 8 1964	K. Jones CDK.
	E	ADDED PART 6	July 14 1964	F. Smith KOL.

EXPLANATION

REVISION A - Indicates general change (see Para. 10.5.1c).

REVISION B - Indicates three specific changes per one E0 (see Para. 10.5.2).

REVISION C - Incorporates two outstanding EOs (see Para. 10.5.2) and status record of a change without E0 to Sheet 2 (see Para. 10.6.1).

REVISION D - Indicates two specific changes per one E0, a change not specified by E0 (Direct Revision) (see Para. 10.5.3.1), and status record of a change by E0 to Sheet 3 (see Para. 10.6.1).

REVISION E - Indicates a direct revision (see Para. 10.5.3).

Figure 10.5-1 Typical Revision Block

DRAWING REVISIONS

10.5.3 REVISIONS NOT SPECIFIED BY EOs

Revisions not specified by EO, may be made by direct revision. When changes are made by direct revision, the revision letter symbol shall be advanced and the change recorded in the revision block (see Figure 10.5-1 Rev. E).

10.5.3.1 EO and Direct Revision

Incorporation of EOs, and direct revisions may be entered in the revision block under the same revision letter symbol. EOs should be listed first (see Figure 10.5-1 Rev. D).

10.5.4 ORIGINAL DRAWING RENEWAL

10.5.4.1 Photographed - No Change

When a new original, without change, is made by any photographic process and legibility is satisfactory without further retouching No revision record shall be required.

10.5.4.2 Redrawn or Photographed and Retouched

When a new original is made by redrawing manually or by photographic methods which required retouching, the revision letter shall be advanced and a statement placed in the "DESCRIPTION" column as shown in Figure 10.5-2.

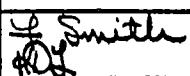
REVISIONS				
ZONE	SYM	DESCRIPTION	DATE	APPROVAL
	F	REDRAWN-NO CHANGE	Aug 20 1964	L. Smith 

Figure 10.5-2. Sample Revision Block Showing Drawing Redrawn - No change.

10.5.4.3 Redrawn and Revised

When a new original is made by redrawing manually or by photographic methods and a change is made, the revision letter shall be advanced. The word redrawn shall be entered in the description column and the changes recorded in accordance with change procedures outlined in Paragraph 10.5.

10.5.4.4 Title Block

When a new original is made by redrawing manually, the names and dates of the individuals who signed and dated the original drawing, should be lettered in the corresponding blocks of the new drawing.

DRAWING REVISIONS

10.6 REVISION STATUS - MULTIPLE SHEET DRAWINGS**10.6.1 MULTIPLE SHEET PART DRAWINGS (without associated PL or RL),**

Multiple sheet part drawings shall have the latest revision letter to any sheet recorded on the first sheet. The last revision letter on the first sheet will be the latest revision to the entire drawing, regardless of the number of sheets. A suitable entry shall be made in the revision block of sheet 1 to record revisions to other sheets in accordance with Figure 10.5-1 Rev. C and Rev. D. This may be the only entry of that revision to sheet 1 (see Paragraph 10.6.1.3).

10.6.1.1 Revision Letter Assignment

All changes that take place at the same time on one or more sheets of a multiple sheet drawing shall be identified by the same revision letter symbol. The revision letter to be used for a change on any sheet will be the next higher letter, in sequence with those recorded on sheet one (see Figure 10.6-1).

10.6.1.2 Adding New Sheets

When adding new sheets, a revision letter shall be recorded in the revision column of the new sheets. The applied revision letter will be the same letter that caused the addition of the sheets. The statement "Sheet Added" shall be recorded in the description column with the initiating EO if required. The total number of sheets shall be changed on sheet one and the final sheet changed as required.

10.6.1.3 Revision Status Block

A tabulated "REVISION STATUS BLOCK" shall be drawn above the title block in accordance with Figure 10.6-1, Sheet 1. The current revision letter of each sheet shall be recorded and sequentially updated for each revision.

10.6.2 ASSEMBLY DRAWINGS AND ASSOCIATED PARTS LIST

The PL will require a lead sheet on which the revision status of sheets for both the Parts List and Assembly Drawing shall be recorded in accordance with Figure 10.6-3 sample Sheet 1.

10.6.2.1 Revision Status on PL Lead Sheet

The lead sheet shall be regarded as part of the drawing and when revisions are made shall be requested simultaneously with every request for tracings of that drawing.

DRAWING REVISIONS

10.6.2.1 (Cont'd)

- a. The "REV" column shall record sequentially every letter change made to the parts list or assembly drawing.
- b. The "DWG" column shall reflect the change status of each sheet of the drawing.
- c. The "PARTS LIST" columns shall reflect the change status of each sheet of the Parts list.
- d. The "REV NOTICE NUMBER" shall reflect the initiating Engineering Order (EO) if required.
- e. For documents that require more than a single row of squares for sheet entries, additional rows may be used by removing the horizontal divider line in the "REV" column.
- f. The assembly "REVISION STATUS BLOCK" shall record the revision letter against the applicable group and shall be the same letter recorded in the "REV" column. Dash marks may be used to denote no affect to a group.

10.6.2.2 Revision Status on Assembly Drawing

The first sheet of the Assembly Drawing shall have a note "For Revision Status, see Sheet 1 of Parts List" in accordance with Figure 10.6-2.

10.6.3 RUNNING LISTS WITH ASSOCIATED ASSEMBLY OR DIAGRAM DRAWINGS

A running list identified with an assembly or diagram drawing shall require a status lead sheet. (See Figure 10.6-3, Sample Sheet 2). Recording of revisions shall be in accordance with Paragraph 10.6.2.1. On an RL lead sheet with associated drawing, a "DWG" column shall be added in accordance with Figure 10.6-3, Sample Sheet 1.

10.6.3.1 Revision Status on Associated Diagram Drawing

Sheet 1 of the associated diagram shall have a note "For Revision Status, see Sheet 1 of Running List" in accordance with Figure 10.6-2.

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10.6.4 "A" SIZE DRAWINGS

"A" size drawings such as written text, procedures, instructions etc, shall require a lead sheet, and the revision change and status recording entered thereon shall be in accordance with this section (see Figure 10.6-3 sample sheet 3).

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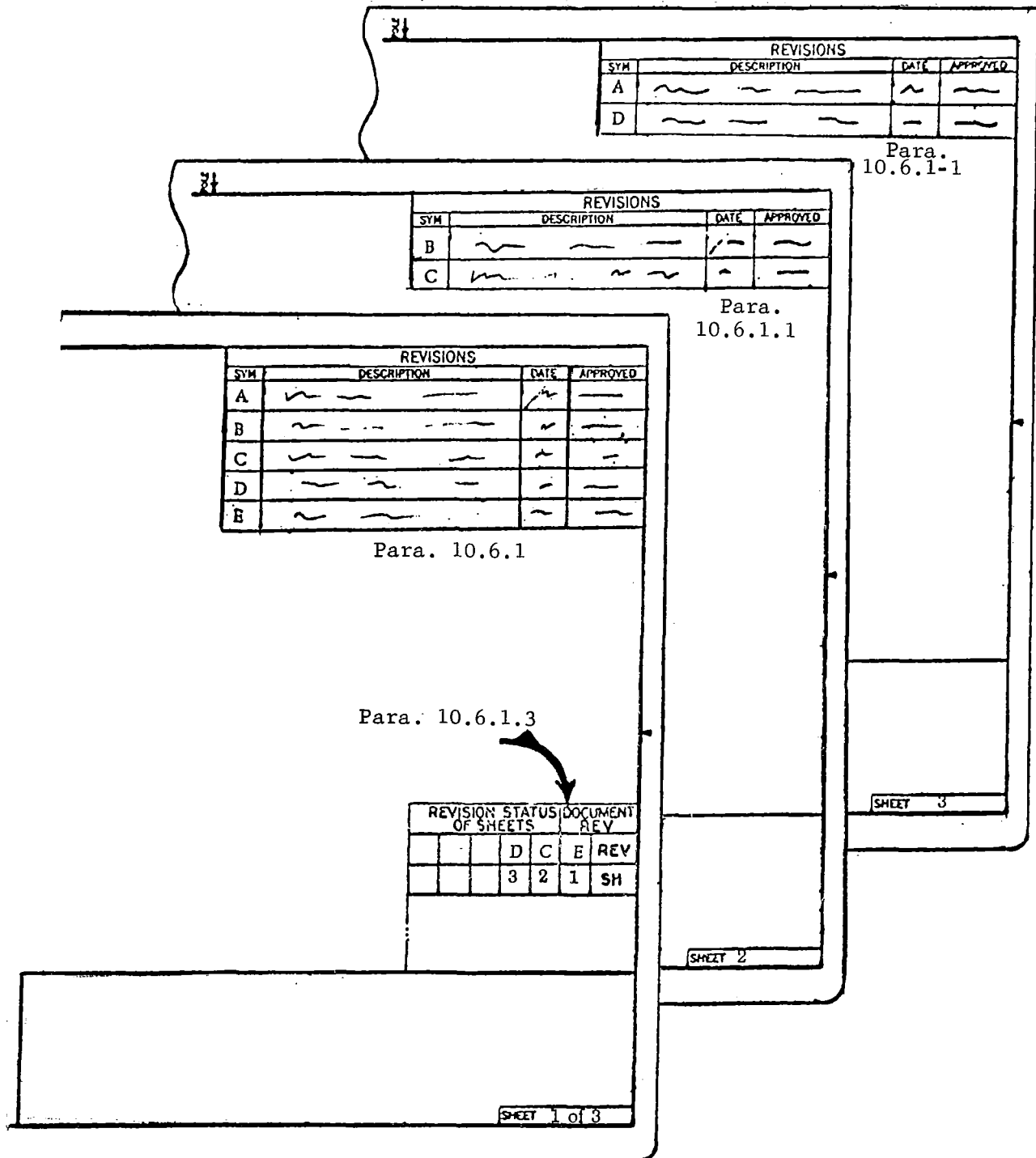


Figure 10.6-1 Multiple Sheet Part Drawings
(Without associated PL or RL)

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Para. 10.6.2.2

FOR REVISION STATUS
SEE SH 1 OF PARTS LIST

REVISIONS			
SYN	DESCRIPTION	DATE	APPROVED
B			

REVISIONS			
SYN	DESCRIPTION	DATE	APPROVED
A			
C			
D			
E			

SHEET 1 of 2

SHEET 2

Figure 10.6-2. Assembly Drawing

Figure 10.6-3 Lead Sheets

REVISÉD



DRAWING REVISIONS

10.7 METHODS FOR REVISING DRAWINGS

Changes to drawings shall be made using the same conventions and following the same techniques that were used on the original. The line work and lettering shall be legible and of reproduction quality. Erasures shall be made so that "ghosts" will not appear on prints.

10.7.1 DELETION OF ITEMS**10.7.1.1 Parts List**

Items shall be deleted from a parts list using horizontal lines drawn through the quantity of the items deleted.

10.7.1.2 Assembly Drawings

All reference to the corresponding item number deleted from the parts list in accordance with Paragraph 10.7.1.1 shall be erased from the field of the drawing.

10.7.1.3 Multidetail Drawing

No method is required to delete a part from a multidetail, monopart or tabulated drawing since only items called for on assembly parts list are authorized to be ordered.

10.7.2 DELETION OF NOTES

Notes that have been cancelled by a change shall be deleted by crosshatching and all reference to the notes erased from the field of the drawing.

10.7.2.1 Deleted Notes - Retraced Drawing

Notes that have been deleted by crosshatching shall be omitted on a retrace. The remaining notes shall be closed up and retain their original note number. If the last note on the original tracing has been crosshatched, its number shall be shown with a notation "Note Cancelled".

10.7.2.2 Adding Notes

When a new note is added to a drawing with its last note cancelled as described in Paragraph 10.7.2.1 the number and notation shall be erased and the new note added using the next higher number.

DRAWING RELEASE AND CONTROL

11.1 GENERAL

This section defines the procedures for the release and control of engineering drawings by drafting personnel. It is intended to provide only information and instructions to enable the draftsman to integrate his activities with others, as necessary, in the release and control of all documentation originating in drafting. Detailed procedures for maintaining release records of engineering data are established and defined in the Engineering Procedures, KD1A0133.

11.2 RELEASE AND CONTROL FORMS

The following forms are used for the release of documents and for the control of changes made to these documents after release:

- a. Engineering Records Visible Index Card (KSC Form 21-67).
- b. Documentation Release Authorization (DRA) (KSC Form 21-68).
- c. Drawing Sheet (KSC Form 21-17).
- d. Engineering Order (EO) (KSC Form 21-34).
- e. Interface Revision Notice (IRN)

11.3 DRAWING RELEASE

All engineering drawings and associated lists shall be released against their applicable hardware or system item designation. Drawing types which shall be released include the following:

- a. Production
- b. Proposal
- c. Layout
- d. B and C Level Interface Control (ICD)

11.4 DRAWING NUMBER ASSIGNMENT

11.4.1 PRODUCTION DRAWINGS AND B AND C LEVEL ICD DRAWINGS

All production drawings and B and C level ICD drawings shall be identified by a number assigned on an individual drawing basis by the Engineering Documentation Center (EDC).

DRAWING RELEASE AND CONTROL

11.4.1.1 Drawing Record

At the time the number is requested, the individual receiving the number shall enter the following information on the Engineering Records Visible Index Card, supplied by EDC:

- a. Drawing size (prefix the drawing number on the card with the drawing size letter).
- b. Nomenclature (enter the title of the drawing).
- c. Next assembly (enter number and size of next higher or using assembly).
- d. Used on (enter the missile or system for which the drawing will be used, e.g., Saturn V, Saturn IB).
- e. Sign and date the card in the "Remarks" space directly below the "used on" and "next assembly" columns.

11.4.2 LAYOUT AND PROPOSAL DRAWINGS

All Layout and Proposal drawings shall be identified by a number assigned by EDC in the same manner as for Production drawings with one exception. To identify the drawing as a Layout or Proposal drawing, the number used on the drawing shall be the number assigned by EDC suffixed with the letter "L" for a Layout drawing and the letter "P" for a Proposal drawing. Examples of Layout and Proposal drawing numbers are:

75M12345L - indicates a Layout drawing.

75M12345P - indicates a Proposal drawing.

Layout and Proposal drawings shall further be identified by the word "Layout" or the word "Proposal", as applicable, placed in the drawing title block preceding the drawing title and a note "Do not use for fabrication."

11.4.2.1 Drawing Record

The recording of Layout and Proposal drawings shall be accomplished by preparing Engineering Records Visible Index Cards, as outlined in Paragraph 11.4.1.1, except the drawing number on the card shall be prefixed with the drawing size letter and suffixed with the letter "L" or "P" as applicable.

DRAWING RELEASE AND CONTROL

11.4.2.2 Use of Same Basic Drawing Number for Layout, Proposal and Production Drawing

Drawing numbers assigned to Layout and Proposal drawings shall, where practicable, be the same basic number which will be assigned to the top production drawing of the item. If, however, there is no correlation between a Layout and/or Proposal drawing and a Production drawing for an item, the basic drawing number used for the Layout and/or Proposal drawing(s) shall not be assigned to a production drawing. In order to preserve the drawing number continuity between production, Layout and Proposal drawings for an item, it will be necessary that EDC be given the drawing type to which each drawing number is to be assigned. Unless stated otherwise by the individual receiving the drawing number, EDC shall assume the number will be used on a production drawing.

It is thus established that the same basic drawing number will apply to a specific top production drawing for an item and to a Layout and a Proposal drawing for the item but that each is differentiated from the others by using the suffixes for the Layout and Proposal drawing numbers, as illustrated by the following example:

75MXXXX1P - indicates a Proposal drawing assigned the number 75MXXXX1.

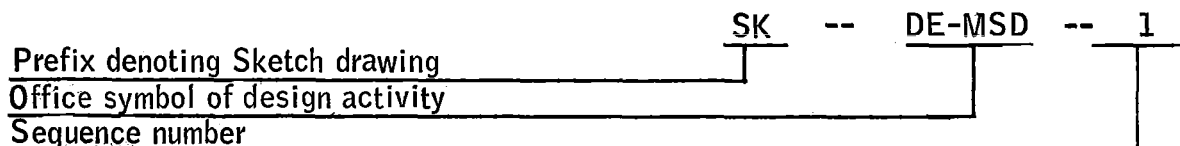
75MXXXX1L - indicates a Layout drawing prepared to establish and define design concepts, clearances, etc., for the basic design advanced by the Proposal drawing.

75MXXXX1 - indicates the hardware or system item top drawing resulting from the Proposal and Layout drawings using the same basic drawing number.

11.4.3 SKETCH DRAWINGS

All Sketch drawings shall be identified by a number assigned by the design section originating the drawing.

Sketch numbers shall be assigned as follows:



DRAWING RELEASE AND CONTROL

11.4.3 (Cont'd)

As an example, the first number assigned by the Mechanical Systems Division will be SK-DE-MSD-1, the second Sketch drawing number will be SK-DE-MSD-2.

11.4.3.1 Drawing Record

The recording and filing of Sketch drawings shall be the responsibility of the originating design section.

11.4.4 UNUSED NUMBERS

When a number has been assigned to a drawing by EDC and, for some reason, it is decided the drawing will not be released, the number shall be immediately returned to EDC, removed from the drawing, and shall not be reused. If, and when, at a later date, the drawing is approved for release, a new number shall be requested of EDC.

11.5 DOCUMENT RELEASE AUTHORIZATION (DRA)

All engineering data approved for release shall be presented to the Engineering Documentation Center (EDC) with a Document Release Authorization (DRA), KSC Form 21-68, prepared in accordance with Engineering Procedures KD1A0133, Procedure No. 10.

11.5.1 TYPES OF RELEASE

There are two basic types of releases applicable to drawings. These are production releases and preliminary releases.

DRAWING RELEASE AND CONTROL

11.5.1.1 Production Release

Production releases shall include all drawings which are considered complete and usable for procurement of materials and components and for the fabrication of equipment. Completed drawings identified as proposal or layout drawings shall be treated as production releases but shall not be used for procurement or fabrication purposes.

11.5.1.2 Preliminary Release

Preliminary releases shall include all drawings which are considered to be incomplete and shall be primarily restricted to situations where it is deemed advisable to issue advance information to other DE areas, other KSC Directorates, or to Contractors. When a preliminary release is to be made, the DRA shall have the words **PRELIM RELEASE** entered, in one-fourth inch high letters, above the **APPROVED** space on the lower right-hand side of the DRA.

All drawings released on a preliminary basis shall be identified as such so they will be recognized as an incomplete drawing not to be used for fabrication or procurement. They shall be identified by the following note prominently lettered on the drawing:

**"PRELIMINARY
LATEST INFO DATE-"**

Drawings with title blocks may have the above note entered in the "approved" signature block.

Preliminary drawings may be revised without employing the revision block by merely changing the information date. In either case, the latest date that information is placed upon the drawing is reflected by the "LATEST INFO DATE" entry.

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DRAWING RELEASE AND CONTROL

11.6 DRAWING REQUISITION OR TRANSMITTAL

Drawing sheet, KSC Form 21-17 shall be used for requisitioning originals or prints of drawings from EDC. The same form shall be used when requesting EDC to transmit originals or prints of drawings to other KSC organizations having a need for them or to contractors who have a need and are qualified to receive them. A Document Release Authorization (DRA), KSC Form 21-68, shall be used to requisition, or request transmittal of reproducibles of drawings from EDC.

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ENGINEERING TERMINOLOGY

12.1 **GENERAL**

The preparation of engineering drawings and associated documentation frequently requires the use of terminology beyond the scope of the usual desk dictionary. Therefore, it is recommended that the NASA Dictionary of Technical Terms for Aerospace Use (NASA SP-7) be used for guidance.



ABBREVIATIONS

13.1 GENERAL

Abbreviations may be used on drawings and associated documents to conserve space only when necessary and when their meanings are unquestionably clear. **WHEN IN DOUBT, SPELL IT OUT.**

13.2 AUTHORIZED ABBREVIATIONS

When abbreviations are used, they shall conform to MSFC-STD-350. Some of the terms, acronyms and abbreviations commonly used at KSC are contained in KSC-GP-589. This document should be used as a guide when the desired abbreviation is not found in MSFC-STD-350.

GRAPHIC SYMBOLS

14.1 GENERAL

Symbols used on drawings and documents prepared for KSC shall be in accordance with the standards listed below.

A symbol for a component or function not listed in this section may be represented by a symbol created by the design activity initiating the drawing, providing that the symbol is supplied in a legend upon any drawing on which it is used.

14.1.1 LIST OF APPLICABLE SYMBOLS

Electrical and Electronics Symbols	KSC-STD-152-1
Logics Symbols	KSC-STD-152-1
Electrical Wiring Symbols - Architectural	KSC-STD-152-1
Component Symbols	KSC-STD-152-1
Symbols for Vehicle-Oriented Flow Diagrams	KSC-STD-152-2
Symbols for Pipe Fittings, Valves, and Piping and Facilities Flow Diagrams	KSC-STD-152-2
Symbols for Plumbing	KSC-STD-152-2
Symbols for Heating, Ventilating and Air Cond.	KSC-STD-152-2
Symbols for Heat Power Apparatus	KSC-STD-152-2
Symbols for Fluid Power Diagrams	KSC-STD-152-2
Dimensioning and Tolerancing Symbols	Section 5
Welding, Brazing and Soldering Symbols	Section 21
Surface Roughness Symbols	Section 8
Non-Destructive Testing Symbols	American Welding Society Standard AWS A2.2-58



IDENTIFICATION MARKING OF PARTS AND EQUIPMENT

15.1 GENERAL

This section defines requirements for configuration identification marking. Other marking requirements, such as special warning, color code identification, and reference designation, are not included in this section.

All items shall be marked for identification purposes as required in stocking and replacing of parts, subassemblies, assemblies, or end items of equipment.

The drawing or specification document for such items shall specify the marking requirements.

All configuration identification information on nameplates or markings shall be taken from and agree with the design drawings or specifications and/or their engineering release records.

15.2 MARKING INFORMATION

When the identification marking is to be marked directly on the item, the drawing or specification for the item shall include marking instructions and state the identification information to be marked on the physical part. When marking instructions are not stated on the drawing or specification, it shall be interpreted to mean the item requires no marking.

When it is required that the information be marked on a nameplate and the nameplate affixed to the item, the identification information shall be specified on the nameplate drawing or specification.

15.2.1 REQUIREMENTS

When general marking requirements are adequate and such things as method of applying and location of marking may be left to the option of the manufacturer, the marking instructions may be stated with a note such as: "Mark (identification information for the item) per KSC-STD-E-0015".

When design considerations dictate certain specific requirements, these requirements must be included in the marking instructions.

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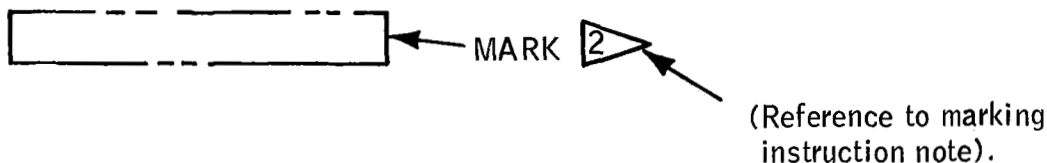
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IDENTIFICATION MARKING OF PARTS AND EQUIPMENT

15.2.1.1 Location

When a specific location for the marking is required, the drawing shall show a phantom block at the desired location, as follows:



15.2.1.2 Method

When a specific method of marking, such as rubber stamp, die stamp, stencil, etc, is required, the requirement shall be included in the marking instructions. For acceptable methods of marking and durability requirements, see KSC-STD-E-0015.

15.2.1.3 (DELETED)

15.2.1.4 Serialization

The marking instructions shall specify serial number marking when required.

All contract end items, engineering critical components, and logistic critical components shall be serialized.

15.3 ITEM MARKING

The following subparagraphs contain the various items that require identification marking and the information required for their identity.

15.3.1 CONTRACT END ITEMS (CEI'S)

Each end item shall be identified with a nameplate arranged as shown in Figure 15.3-1 and contain the information shown thereon.



IDENTIFICATION MARKING OF PARTS AND EQUIPMENT

— CONFIGURATION IDENTIFICATION —

MODEL 10A001A SERIAL NO. 15

PART NO. 75M12345-1

SPEC. CS10A001A DESIGN CODE 38415

— SUPPLY DATA —

STOCK NO. 5840-480-1234

RADAR, SEARCH, LAND MOBILE

CONTRACT 33(614)-12345 MFR. CODE 24831

MILITARY ELECTRONICS CO.
NASA

NOTES:

1. CONTRACT END ITEM NUMBER
2. CONTRACT END ITEM SERIAL NUMBER
3. CONTRACT END ITEM PART NUMBER
4. CONTRACT END ITEM DETAIL SPECIFICATION AND REVISION NUMBER
5. DESIGN ACTIVITY CODE FROM CATALOGING HANDBOOK H4-1
6. FEDERAL STOCK CLASS AND FEDERAL ITEM IDENTIFICATION NUMBER
7. NOMENCLATURE
8. MANUFACTURING CONTRACT NUMBER
9. MANUFACTURER'S CODE FROM CATALOGING HANDBOOK H4-1
10. MANUFACTURER'S COMPANY NAME
11. GOVERNMENT OWNERSHIP SYMBOL

Figure 15.3-1. Sample Contract End Item Nameplate

IDENTIFICATION MARKING OF PARTS AND EQUIPMENT

15.3.1 (Contd)

NOTE

CEI nameplates shall be located for convenient examination by service and operating personnel when the CEI is in an operationally ready position.

15.3.2 ENGINEERING CRITICAL COMPONENTS

Each engineering critical component, when part of a CEI, shall be identified with a nameplate arranged as shown in Figure 15.3-1 and contain the information shown thereon except:

- a. Note 1 "leave blank".
- b. Note 2 shall be the part serial number (not the CEI serial number).
- c. Note 3 shall be the part number of the engineering critical component (not the CEI part number).
- d. Note 4 shall be the specification and revision number of the engineering critical component specification (not the CEI Detail Specification and revision number).

15.3.3 IDENTIFICATION ITEMS

Each identification item shall be identified by a nameplate, or equivalent, containing the "CONFIGURATION IDENTIFICATION" data shown in Figure 15.3-1, notes 1 through 6.

15.3.4 REQUIREMENT ITEMS

Requirement items are GFE and shall be re-identified only as required by TCTR's which are accomplished and logged in historical records supplied with GFE. When a requirement item is altered or selected, it shall be identified as a contract end item in accordance with Paragraph 15.3.1 or 15.3.3, or as a part thereof.



IDENTIFICATION MARKING OF PARTS AND EQUIPMENT

15.3.5 MINIMUM MARKING REQUIREMENTS FOR CEI's AND COMPONENTS

CEI's and engineering critical components, which are too small for complete identification, shall be marked with the following minimum configuration data:

- a. The part number.
- b. The serial number.
- c. The design activity code identification number and the manufacturer's code identification number, if different (see Section 7).

15.3.6 NON-KSC DESIGNED ITEMS

Non-KSC designed items purchased to a KSC specification control drawing or source control drawing (see Section 7, Paragraph 7.5 c and d) shall be marked with the following minimum identification data:

- a. The item design activity's part number.
- b. The KSC identification number for the item in parentheses.
- c. The serial number, if used (see Paragraph 15.2.1.4).
- d. The design activity code identification number and the manufacturer's code identification number, if different (see Section 7).

15.3.7 ALTERED OR SELECTED ITEMS

When an item is altered or selected for certain elements, dimensions, tolerances, characteristics, or functions, the part number assigned by the activity making the alteration or selection shall be marked on the item and the original part number shall be obliterated without damage to the item.

15.3.8 SUBASSEMBLIES AND ASSEMBLIES

The following information shall be marked on all subassemblies and assemblies not covered in Paragraphs 15.3.1 thru 15.3.7:

IDENTIFICATION MARKING OF PARTS AND EQUIPMENT

15.3.8 (Contd)

- a. The part number.
- b. The serial number, if used (see Paragraph 15.2.1.4).
- c. The design activity code identification number and the manufacturer's code identification number, if different (see Section 7).

Whenever space permits, the following additional information shall be included as applicable:

- a. Nomenclature.
- b. Stock number.
- c. Pertinent information such as rating, operating characteristics, etc.

The notation "(ASSY)" shall be marked as a prefix to the subassembly or assembly identifying number to differentiate the subassembly or assembly identifying number from the part identifying numbers.

15.3.9 PARTS

All parts shall be individually marked with their part number or standard specification identification number, serial number if used (see Paragraph 15.2.1.4), the design activity code identification number, and the manufacturer's code identification number, if different, except the following:

- a. Commonly known commercial parts which present no identification problem.
- b. Parts which are too small, or would be physically or functionally damaged by this identification.
- c. Parts which are encapsulated within another or otherwise permanently assembled and are not replaceable as a unit.
- d. Parts which are a permanent part of a constructed facility.

15.3.9.1 Matched Parts

Parts which must be mated and for which replacement as matched set or pair is essential, shall be marked with a single part number to designate each matched set or pair.

REFERENCE DESIGNATIONS

16.1 MECHANICAL AND ELECTROMECHANICAL REFERENCE DESIGNATIONS (FINDING NUMBERS)

Finding Numbers (often called System Find Numbers or Mechanical Find Numbers) identify mechanical and electromechanical components of a system on mechanical schematics. Each Finding Number is used for one particular part only; that is, each part, including each application of identical parts, will be assigned a different Finding Number. Finding Numbers will be assigned by the responsible KSC design activity.

16.1.1 USE ON DRAWINGS

When used on drawings in conjunction with Electrical Reference Designations, etc, the Finding Number shall be enclosed in a "racetrack" approximately 1/4 inch wide with the length as required.

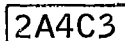
Example:  A2050

16.2 ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS

Each electrical or electronic part, subassembly, assembly, and unit of an electrical system shall be identified by an Electrical Reference Designation in accordance with MSFC-STD-349.

16.2.1 USE ON DRAWINGS

When used on drawings in conjunction with Finding Numbers etc, the Electrical Reference Designation shall be enclosed in a rectangular block approximately 1/4 inch wide with length as required.

Example:  2A4C3

16.2.2 CABLE AND PLUG DESIGNATION

The following procedure, described in KSC-STD-152-1, for assigning Reference Designations to cables and plugs meets the requirements of MSFC-STD-349 and further expands the method of assigning these designations.

1. Basic cable number is same as that of lowest designated interface of the cable.

Example: a. A cable between 1252 and 1256 would be designated 1252W ____.
b. A cable between 1257A4 and 1257A7 would be designated 1257A4W ____.

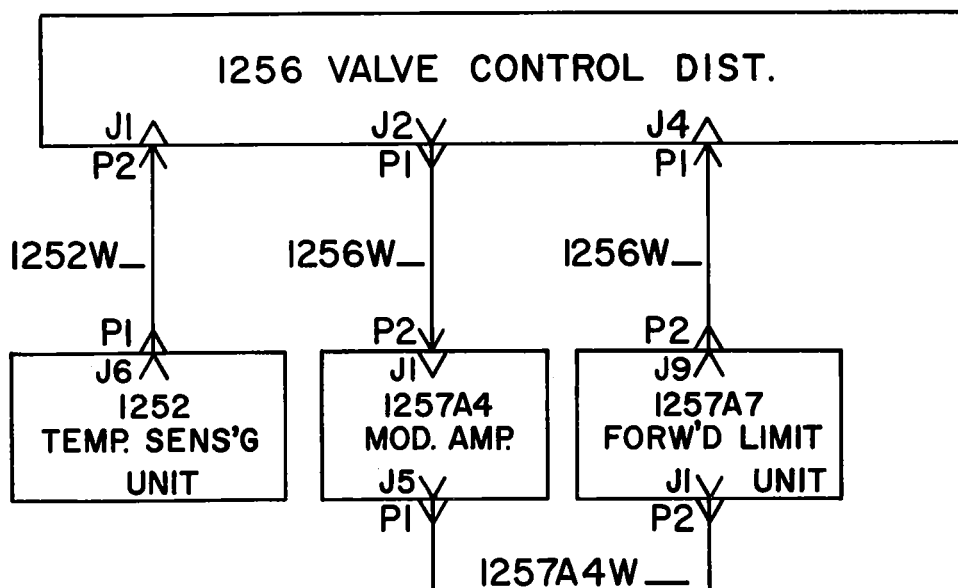
REFERENCE DESIGNATIONS

16.2.2 (Contd)

2. Method of assignment of the W number to cables shall be determined by the specific design activities.
3. P number of cable plug at lowest designated interface would be designated P1; P number at higher or next higher designated interface would be designated P2, etc.

Example: a. The plug at the 1252J6 end of a cable connecting 1252J6 and 1256J1 would be designated short sign P1 (full sign 1252W__P1).

b. The plug at the 1256J1 end would be designated short sign P2 (full sign 1252W__P2).



ELECTRICAL PRACTICE

17.1 GENERAL

This section sets forth the requirements and procedures for the preparation of electrical and electronic drawings.

17.1.1 DEFINITION

Electrical and electronic drawings present the concepts and/or organization of systems, subsystems, assemblies, and component parts. These drawings establish, by means of graphic symbols or simplified wiring views interconnected by lines, the function or wiring connection of an electrical or electronic circuit.

17.1.2 SYMBOLOGY

Electrical and electronic symbology shall be in accordance with Standard KSC-STD-152-1. The template shown in this standard shall be used to form the size and shapes of the symbols that will appear on drawings.

17.1.3 REFERENCE DESIGNATIONS

Reference designations shall be in accordance with Section 16.

17.1.4 ABBREVIATIONS

Abbreviations shall be in accordance with Section 13. Abbreviations shall be used only when space limitations on the drawing lend to the application; otherwise, when possible, the word shall be spelled out.

17.1.5 DRAWING NOTES

Drawing notes, where applicable, shall be of the type and as specified in Section 9.

17.1.6 TYPES OF DRAWINGS

Drawing types and their definitions shall be in accordance with Section 2.

17.2 SCHEMATIC DIAGRAMS

Schematics shall be drawn with area breakdown. Area division lines shall be horizontal and circuits shall progress from left to right. The circuit operation shall be from top to bottom and progress from left to right in order of sequence operation. These rules shall apply wherever possible.

ELECTRICAL PRACTICE

17.2 (Contd)

The interrupted bus symbol is used to indicate further connection without a continuously drawn line; identification is assigned with a letter, a numeral, and a polarity sign.

Multiple-pole switches may be shown with physically separated poles on a schematic, provided they are connected by a broken line to show mechanical linkage.

Reference balloons, most commonly used to show an electrical connection from one sheet to another, may also be used to show mechanical connections from sheet to sheet, if the broken line symbol for mechanical connection is used. Reference balloons using the same number shall connect only two points. (See KSC-STD-152-1.)

Switches, relays, and other devices having moving contacts shall be shown in the OFF or deenergized position.

Symbols should be aligned and drawn vertically, when possible. Horizontally drawn symbols will be acceptable when absolutely necessary.

Symbols should be spaced so that interconnection lines are as straight (without offset) as possible. Curved interconnection lines shall not be permitted. Crossing of lines shall be avoided where possible.

17.2.1 ADVANCED

The advanced schematic shows all of the information of a wiring diagram except for wire routings. This type of schematic is most useful for maintenance and trouble location. (See figure 17.2-1 for a typical advanced schematic.)

17.2.2 ELEMENTARY

The elementary schematic is basically the same as an advanced schematic but omits much of the detailed wire connections of the component items. This type of schematic is most useful as an engineering development drawing and for explanation of system operations or design. (See figure 17.2-2 for a typical elementary schematic.)

ELECTRICAL PRACTICE

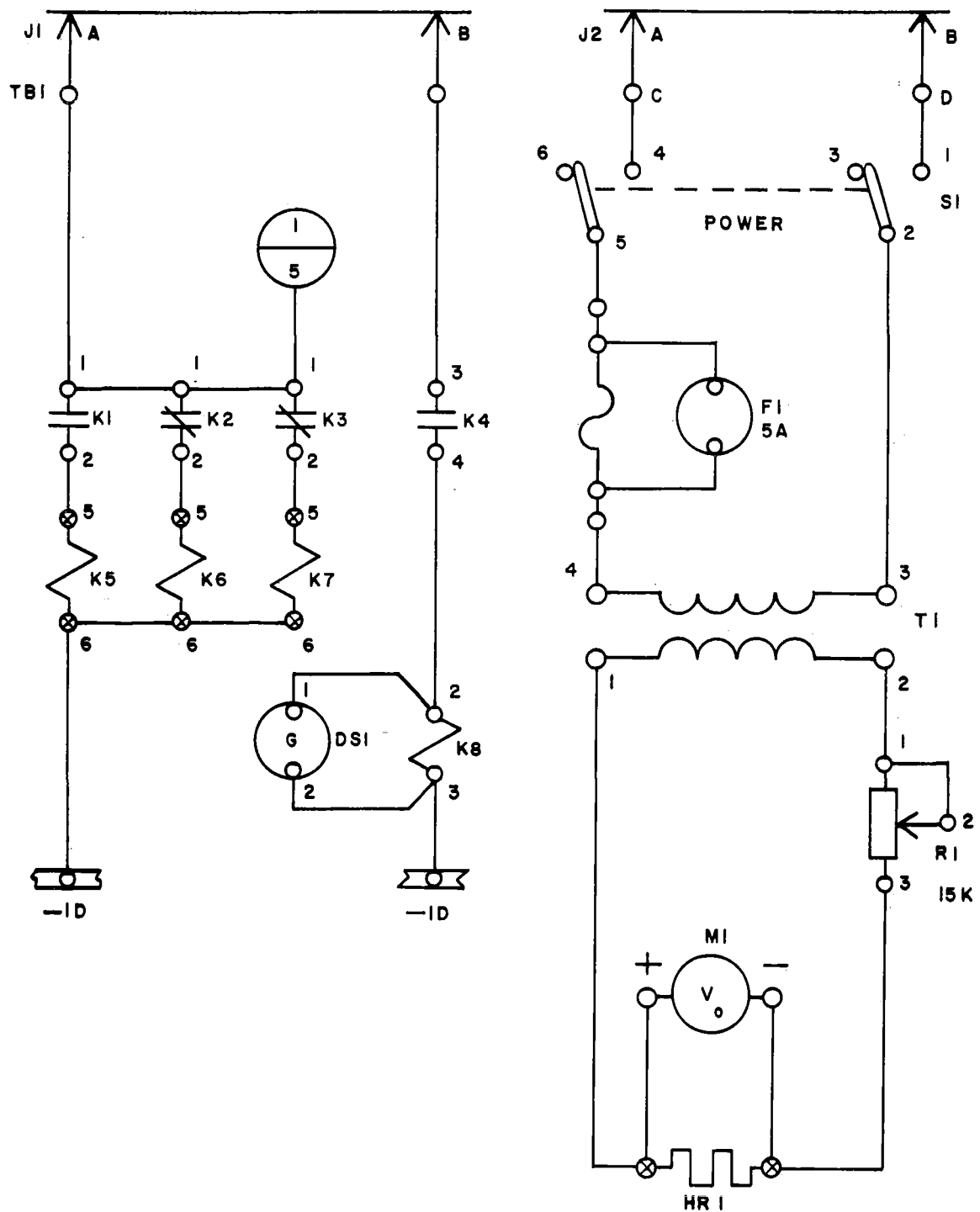


Figure 17.2-1. Typical Advanced Schematic

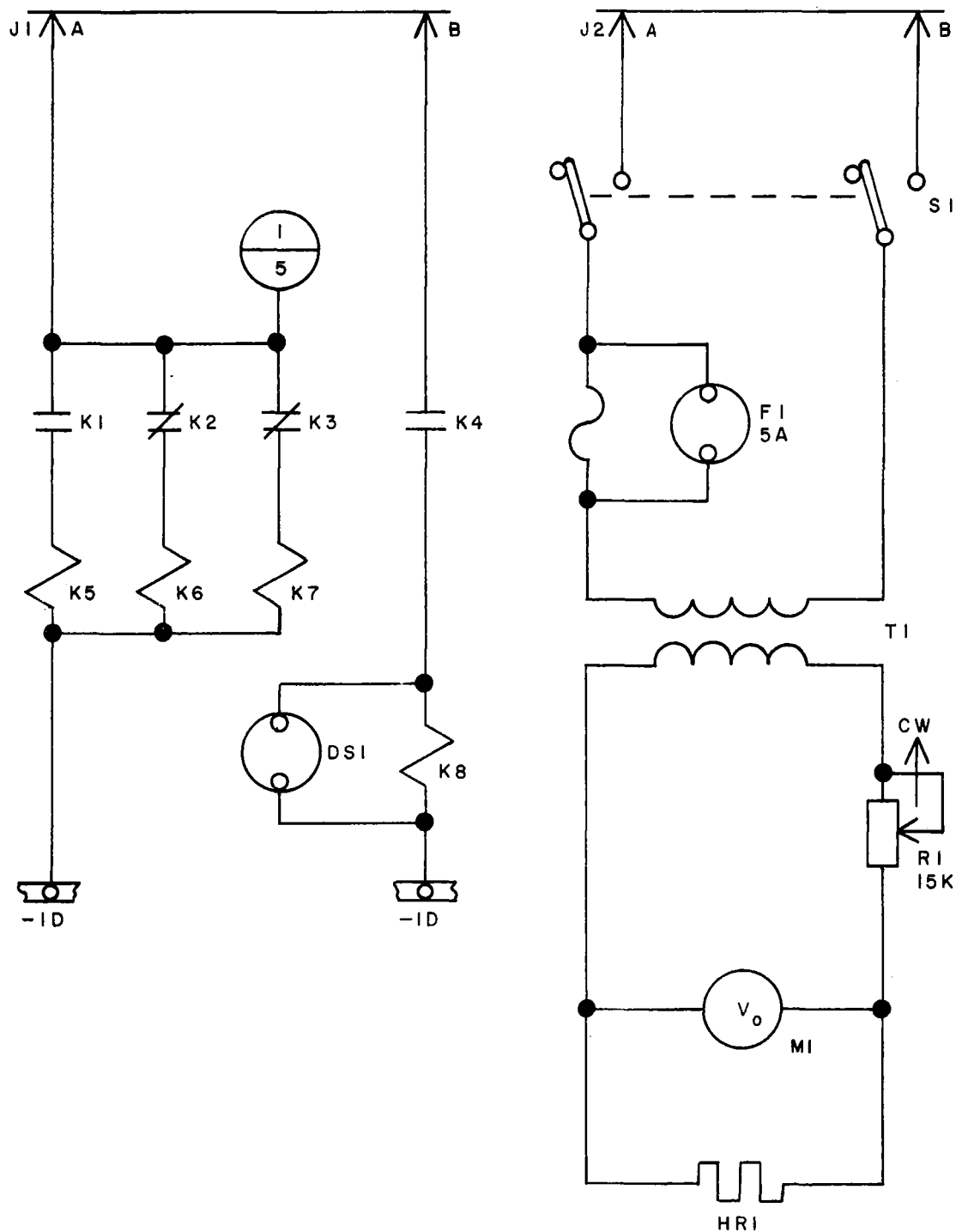
ELECTRICAL PRACTICE

Figure 17.2-2. Typical Elementary Schematic

ELECTRICAL PRACTICE

17.3 WIRING DRAWINGS

This group of drawings includes wiring or connection diagrams which show pictorially and/or by list the connections of an overall system or an individual unit within an overall system.

17.3.1 WIRING OR CONNECTION DIAGRAM

A wiring or connection diagram shows the connections of an installation or its component devices or parts. It may cover internal or external connections, or both, and it contains such details as are needed to make or trace connections that are involved. It usually shows the general physical arrangement of the component devices or parts. The wiring or connection diagram is not complete in itself but must be used in conjunction with a Running List. (See paragraph 17.3.2.)

Wires (connections) shall be numbered to correspond with those on the Running List. Wire size and color coding are normally shown only on the Running List. However, components with attached leads may need to be identified by color. As this type of diagram may be used in the field, it is necessary to show all terminals of all components in their proper locations. (See figure 17.3-1 for a typical wiring or connection diagram.)

17.3.2 RUNNING LIST

A Running List is a tabular drawing specifying wiring data that supplements the information contained on a wiring or connection diagram. It provides wiring information, in convenient list form, pertinent to manufacturing. Figure 17.3-2 is an example of a Running List and shows the type of information normally included.

17.3.3 INTERCONNECTION DIAGRAM

An interconnection diagram shows the interconnection between components of a system. The arrangement is a symmetrical form clearly showing outlines of components with reference to all connecting mediums between the components. The components are located in positions that clearly show the interconnections but are not necessarily in the positions set up for actual operation. (See figure 17.3-3.)

17.3.4 BLOCK DIAGRAM

A block diagram is a line drawing with block outlines to designate units of functional groups for information such as general arrangement studies, functional explanations, and product familiarization within a system, set, or item. (See figure 17.3-4.)

ELECTRICAL PRACTICE

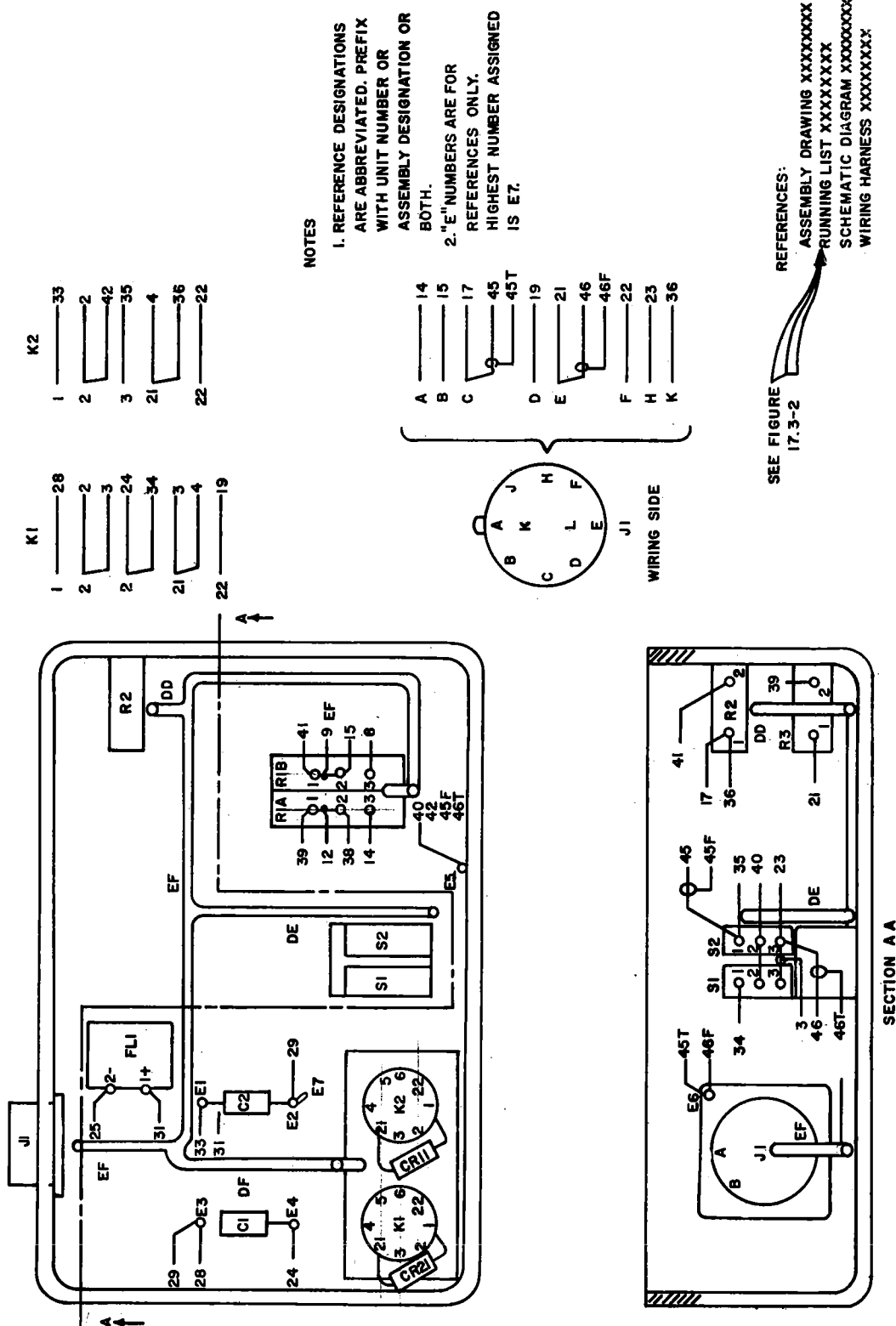


Figure 17.3-1. Typical Wiring or Connection Diagram

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TITLE					CODE IDENT NO.		RL 000000000		SH NO.	CONT. ON	REV
AUDIO AMPLIFIER, CONNECTION DIAGRAM, RUNNING LIST					00000				2	3	
WIRE NO.	WIRE OR COMPONENT	WIRE ITEM NO.	TERM ITEM NO.	SLV ITEM NO.	FROM	TO	SLV ITEM NO.	TERM ITEM NO.	NOTES OR REMARKS		
1	WIRING OF LEFT PANEL										
2	22 BARE	2			E1	E2					
3	20 BARE	3			E3	E4					
4	20 BARE	3			E3	E1-2					
5	W	30									
5A	22W		20	21	TB1-1	TB2-10	26	20		4	
5B	22Y		20	22	TB1-2	TB2-2	27	20		4	
6	22R	5			E1	TB1-3	23	20		4	
7											
8											
9	WIRING OF RIGHT PANEL										
10	22 BARE	2			E36	E37					
11	22 BARE	2			E38	E37					
12	22R	5			E35	T1-4					
13	22K	4			E39A	T1-5					
14											
15											
16	WIRING OF MAIN FRAME										
17	W	31									
17A	22W		20	21	TB1-1	E5				4	
17B	22K		20	24	TB1-5	L1-1				4	
17C	22R		20	23	TB1-3	Q1-E				4	
17E	22K	4		15	SHIELD	TB1-7	25	20		4 9	
17T	22K	4		15	SHIELD	E13				9	
18	20R	12		16	J1-A*	T1-1				8	
19	20K	11		16	J1-P	T1-2				8	
20	COAX	13			J2	E6A					
20F					SHIELD						
20T	22K	4		14	SHIELD	E13					
21	22K	4	20	25	TB1-7	E13				4	
22	22W	10			E5	E30					
23	22W	10		16	PI-A	E8				8	
MADE BY		DATE ISSUED		REVISION AUTHORITY		RL 000000000		SH NO.	CONT. ON	REV	
G. Drafter		21 DAY 9 MO 63 YR									
					DISTRIBUTION CODE						

Figure 17.3-2. Example of a Running List

REVISED

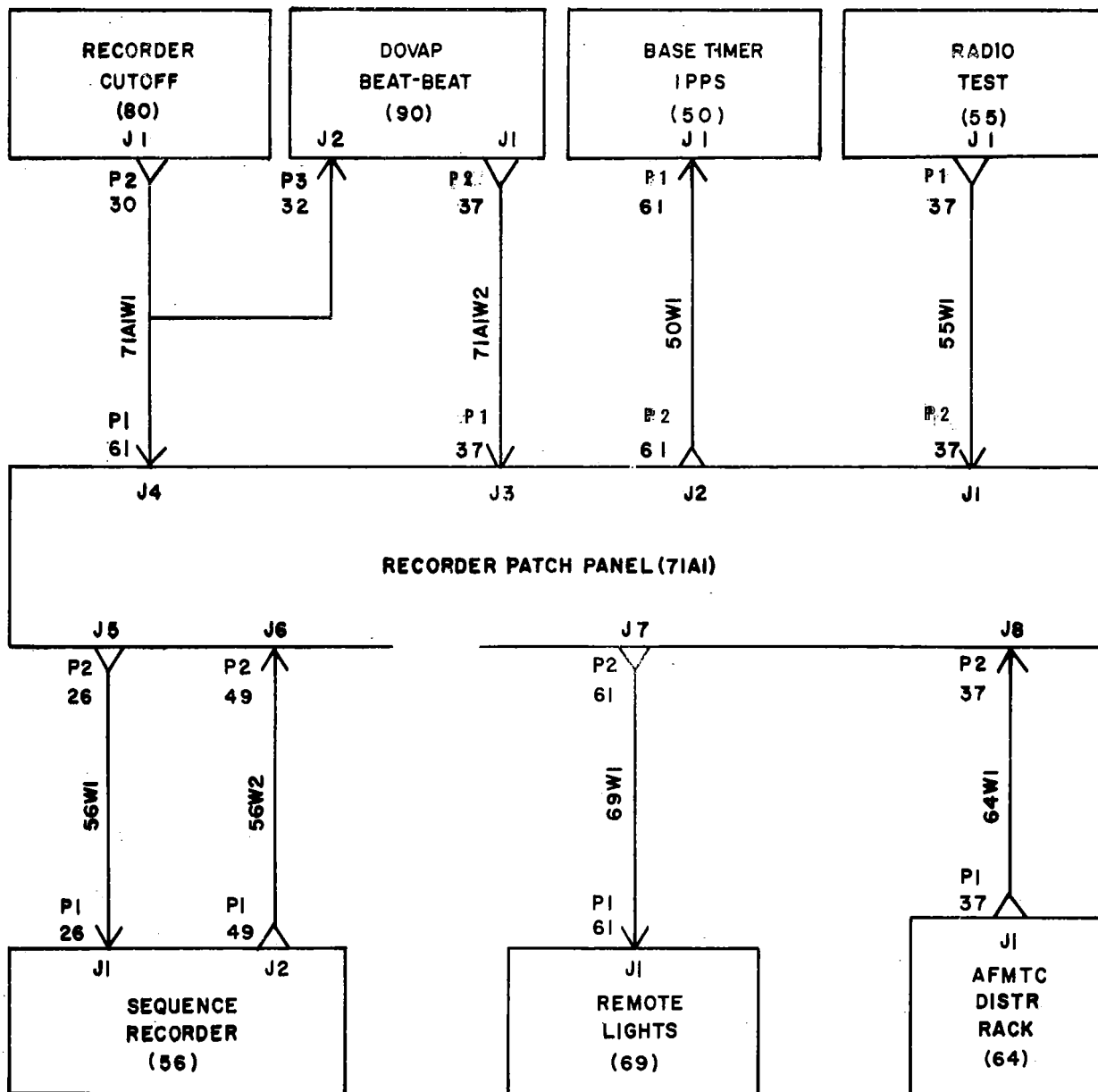


Figure 17.3-3. Example of an Interconnection Diagram

ELECTRICAL PRACTICE

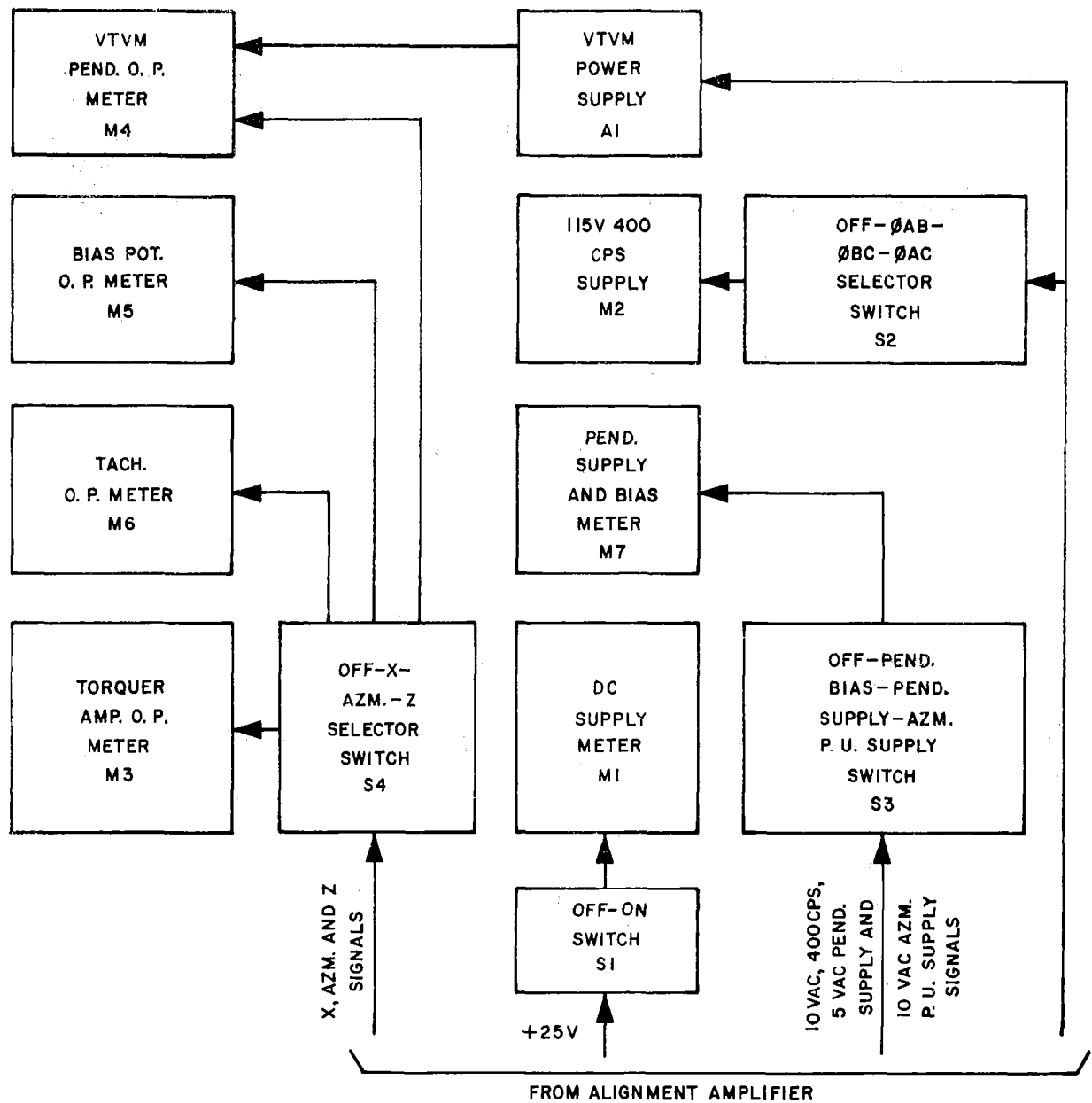


Figure 17.3-4. Example of a Block Diagram

ELECTRICAL PRACTICE

17.3.5 CABLE LENGTH OR ASSEMBLY DRAWING

A cable length drawing shows single or branched cable assemblies (wire bundles or harnesses) in schematic form for the purpose of indicating the lengths between terminals and/or branch points.

The dimensions may be determined by layout or actual development on mockup or prototype. Tolerances shall be specified as liberally as possible commensurate with the length, routing, and application. A note shall clearly define how the measurements are to be taken unless it is obvious from the picturization. The cable and connectors shall be identified with reference designations where applicable. (See figure 17.3-5.)

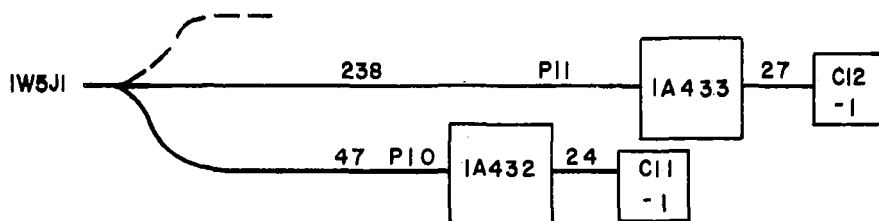


Figure 17.3-5. Cable Length Drawing

17.3.6 CABLE INSTALLATION DRAWING

A cable installation drawing shows the general routing, attaching hardware and information to locate, position, and mount cable assemblies relative to fixed positions on supporting structure. It shall carry adequate information for identity of cables, mating connectors, terminations, and critical clearances or support points. Information necessary for lacing, taping, protective coating, electrical bonding, etc., shall be specified on the drawing or by reference to applicable documents. (See paragraph 17.7.) A typical cable installation drawing is shown on figure 17.3-6.

ELECTRICAL PRACTICE

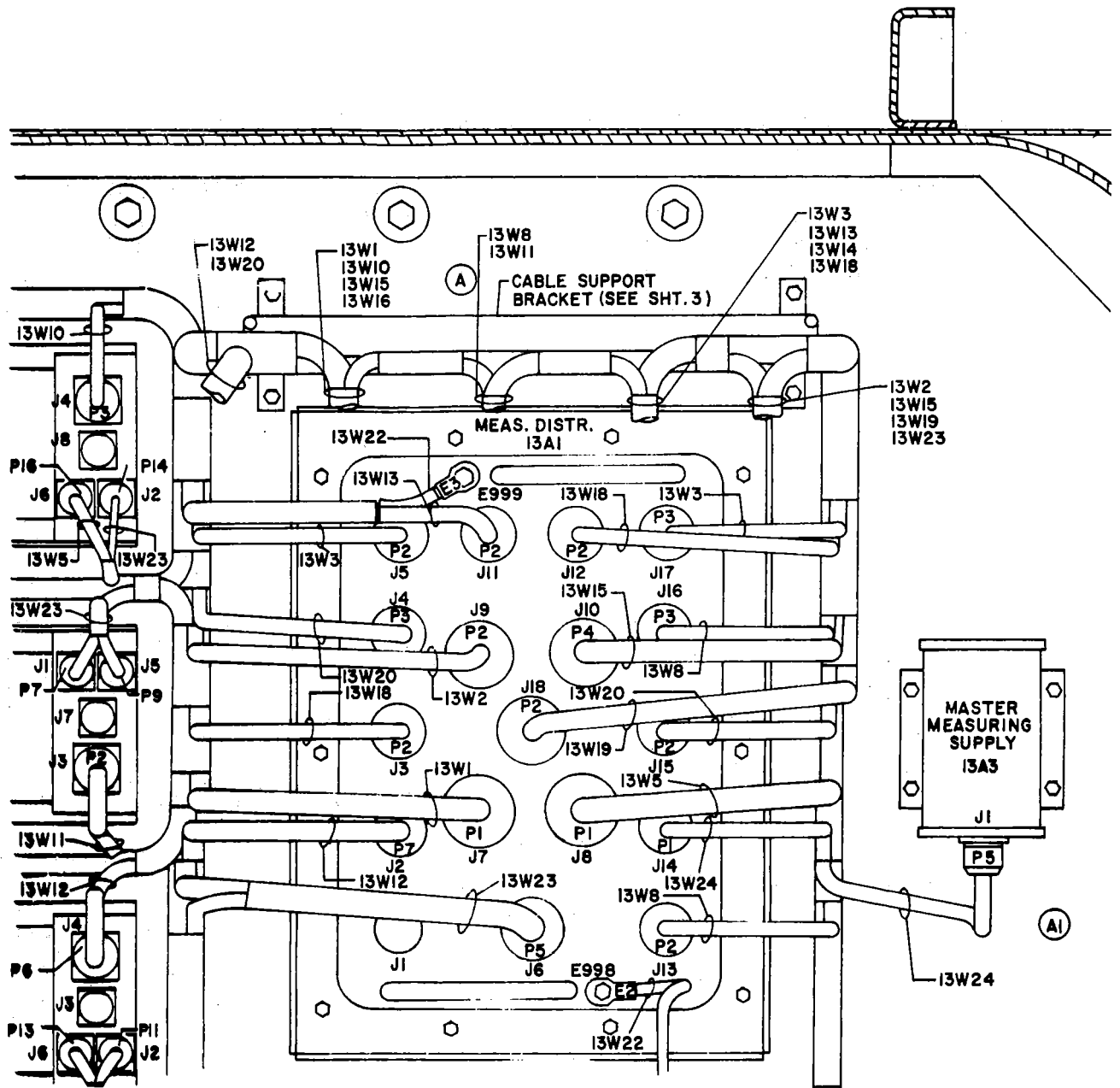


Figure 17.3-6. Typical Cable Installation Drawing

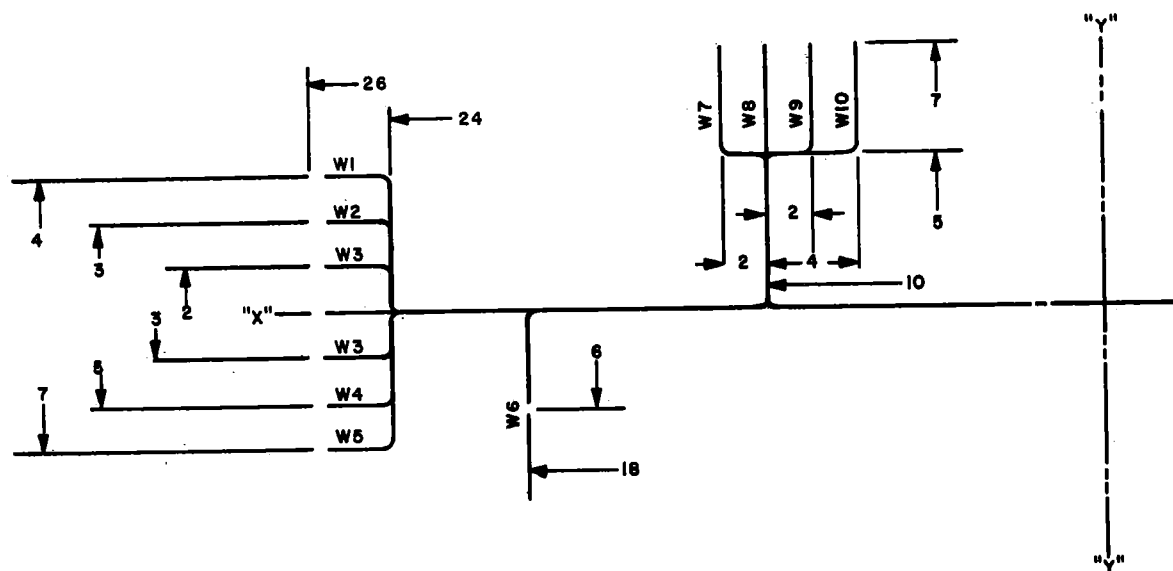


ELECTRICAL PRACTICE

17.3.7 WIRING HARNESS

The wiring harness defines a group of wires, laced together in advance of final assembly, which provides the electrical connection within a unit or assembly. The drawing shall provide the information necessary to accumulate and combine wires in designated routes or branches prior to being wired to an assembly, unit, or groups of units.

A single line shall be used to depict the harness. It is not necessary to delineate the harness to scale; however, dimensions shall be given to locate wire ends and branchouts. When connectors, terminals, lacing tape, etc., are provided as part of the harness, they shall be referenced on the delineation. (See figure 17.3-7.)



Note: All dimensions taken from datum lines X-X or Y-Y.

Figure 17.3-7. Example of a Wiring Harness



ELECTRICAL PRACTICE

17.4 PRINTED WIRING DRAWINGS

Printed wiring is a wiring technique developed to decrease the size and weight of electronic assemblies. Utilization of the technique requires the preparation of specialized documentation. The following subparagraphs show the types of drawings used in the preparation of printed circuit assemblies. Because of the number of different processes available for the preparation of wiring board masters, no attempt will be made to present any of these processes.

17.4.1 PRINTED WIRING ASSEMBLY

A printed wiring assembly is a printed wiring board on which separately manufactured component parts have been mounted. A list of circuit components may be included for ease of maintenance. (See figure 17.4-1.)

17.4.2 PRINTED WIRING BOARD

A printed wiring board is a completely processed conductor pattern, or patterns, usually formed on a rigid, flat base. (See figure 17.4-2.)

17.4.3 PRINTED WIRING MASTER

A printed wiring master is a drawing showing the dimensional limits, terminal areas, and conductor routing. It is drawn on a stable base material. (See figure 17.4-3.)

17.5 LOGIC DIAGRAMS

A logic diagram describes, by means of standard logic symbols and supplementary notations, the details of signal flow and control existing in a digital device, or portions thereof. The logic diagram may, but does not necessarily, indicate point-to-point connections that exist in a network of logical elements. The following subparagraphs describe the various types of logic diagrams.

17.5.1 ELEMENTARY

An elementary logic diagram depicts logic functions without reference to physical implementations. It contains a minimum amount of detail and primarily employs logic symbols to depict logic relationships. Nonlogic functions are not normally shown. Notations shall be included as necessary to provide a complete understanding of the logic design.

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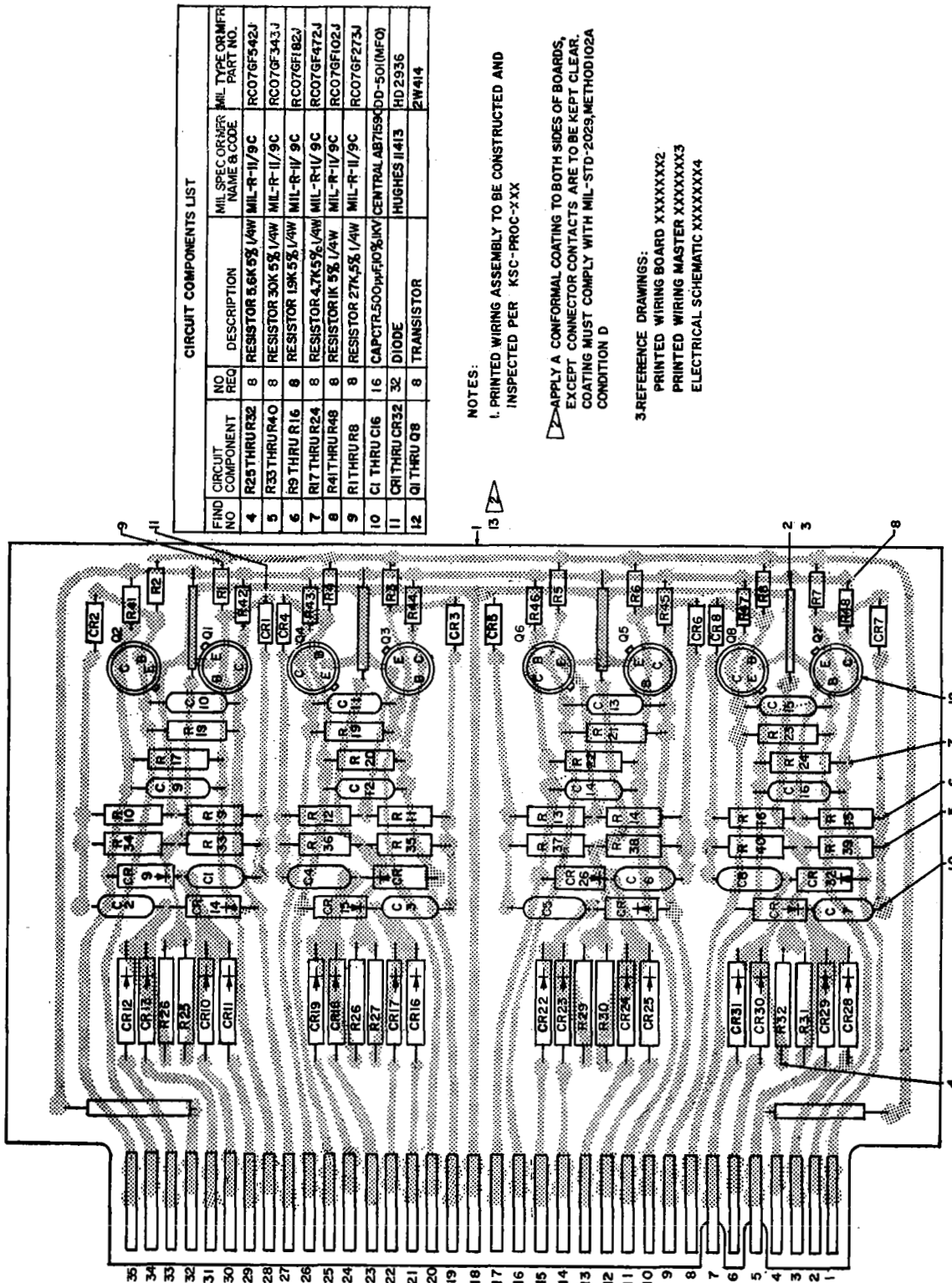
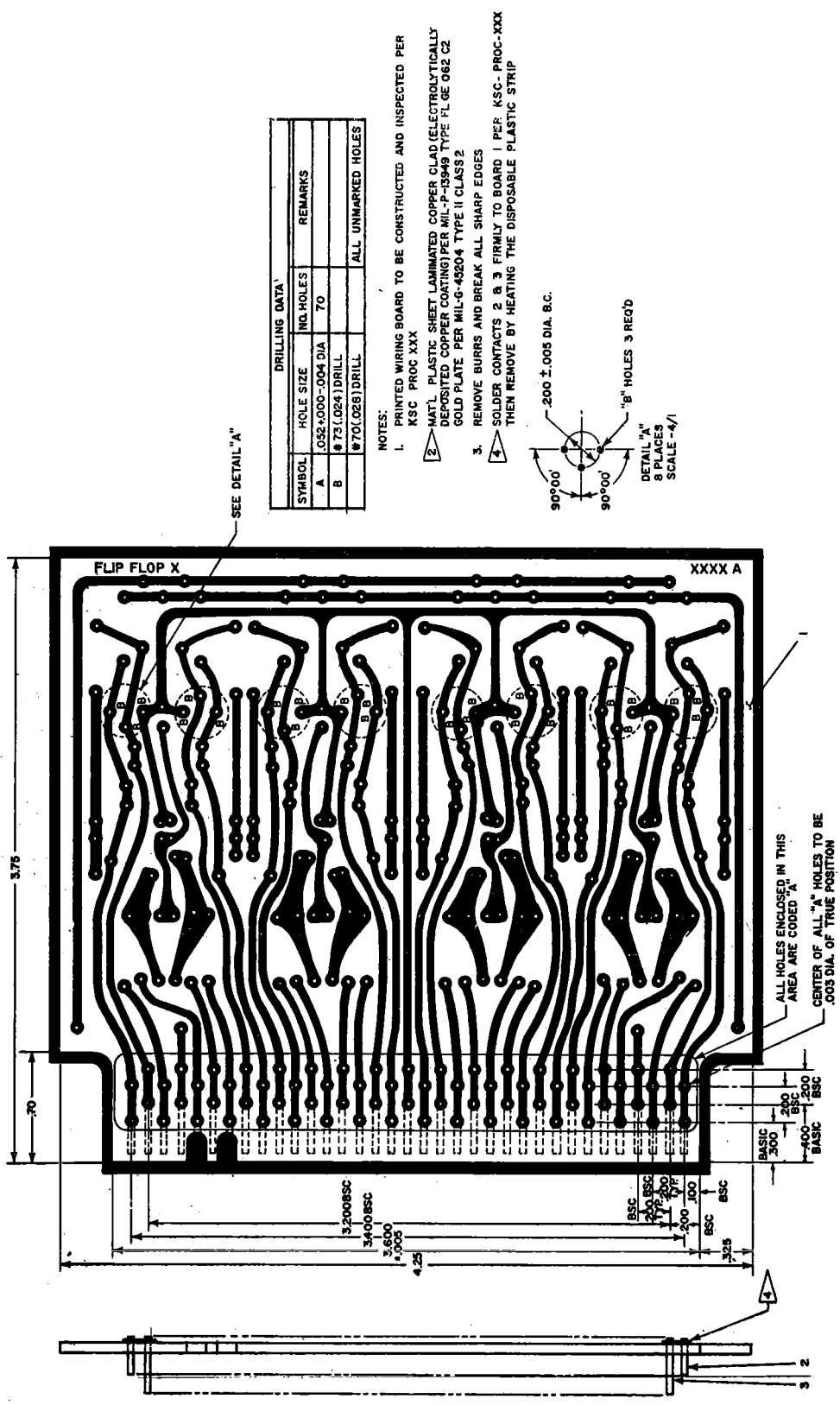


Figure 17.4-1. Example of a Printed Wiring Assembly Drawing

ELECTRICAL PRACTICE





ELECTRICAL PRACTICE

NOTES:

1. THE ORIGINAL OF THIS DRAWING OR REPRODUCTION, WHICH IS MADE BY A METHOD OR PROCESS THAT WILL INSURE DIMENSIONAL STABILITY, IS AN ACCURATE TEMPLATE TO BE USED TO REPRODUCE PRINTED WIRING BOARD XXXXXX2. THE LENGTH VARIATION IN ANY DIRECTION SHALL NOT EXCEED .001 INCH PER FOOT OF LENGTH.
2. THIS TEMPLATE IS PREPARED TO AN ENLARGED SCALE AND MUST BE REDUCED TO ACTUAL SIZE TO PRODUCE THE PRINTED WIRING BOARD.
3. PRINTS OF THIS DRAWING ARE FOR REFERENCE ONLY.
4. REFERENCE DRAWINGS:
PRINTED WIRING ASSEMBLY XXXXXX1
PRINTED WIRING BOARD XXXXXX2
ELECTRICAL SCHEMATIC XXXXXX4

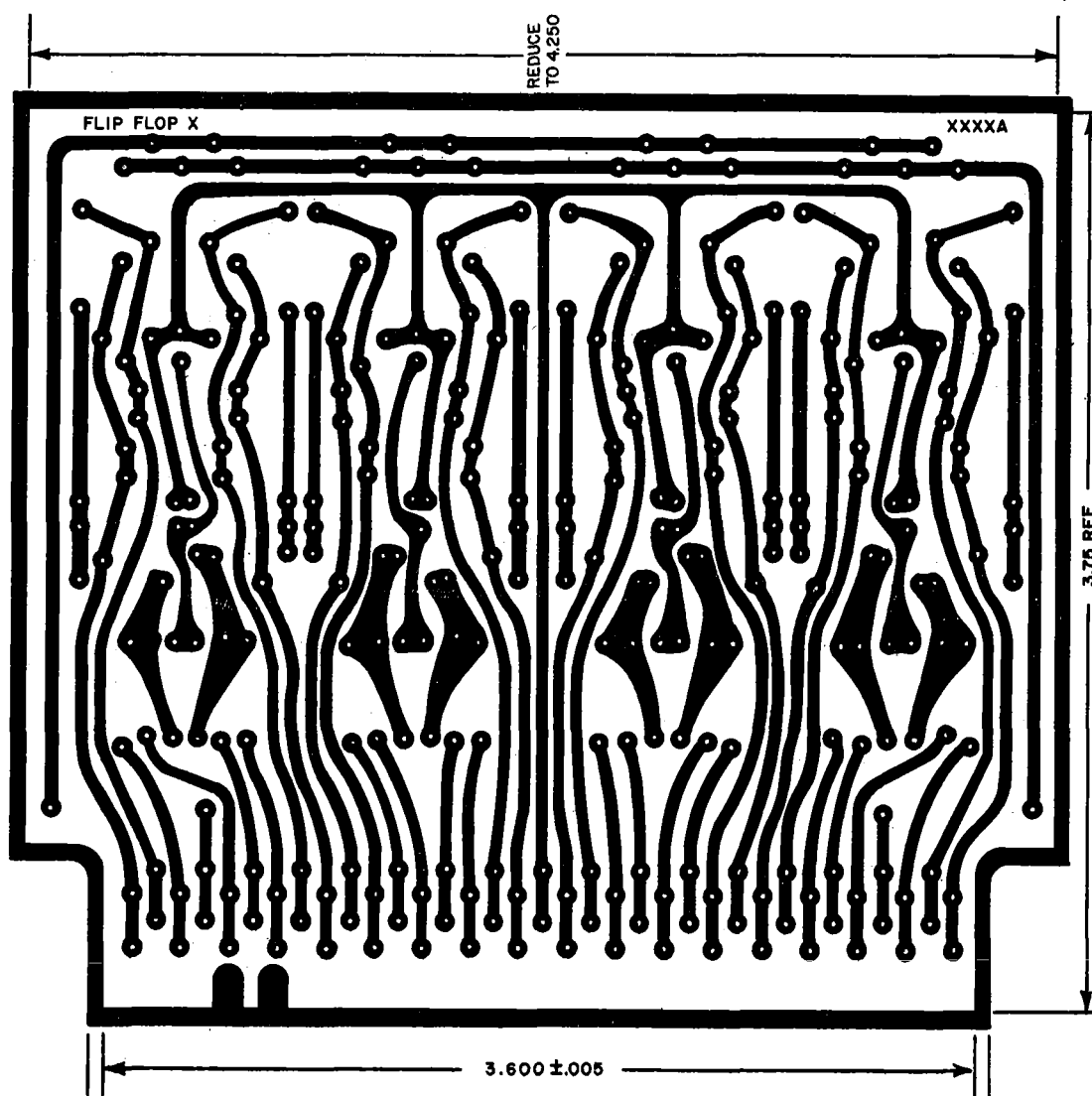


Figure 17.4-3. Example of a Printed Wiring Master Drawing

ELECTRICAL PRACTICE

17.5 (Contd)

17.5.2 ADVANCED

An advanced logic diagram depicts all logic functions and also shows nonlogic functions, socket locations, pin numbers, test points, and other physical elements necessary to describe the physical and electrical aspects of the logic.

17.5.3 FUNCTIONAL

A functional logic diagram describes, by means of standard logic symbols and supplementary notations, the functional flow of interdependent phases of operation within an operational mode. The logic symbols represent electromechanical, mechanical, and other systems necessary to accomplish the function indicated by the symbols. Notations shall be included as necessary to provide a complete understanding of the functional aspects of the mode represented by the drawing. (See KSC-STD-152-1 for symbology and examples of logic diagrams.)

17.6 DETAIL REQUIREMENTS

Detail requirements such as drawing format, drafting practices and routines, drawing titles, and parts identification shall be in accordance with the appropriate sections of this manual.

17.7 GROUND SUPPORT EQUIPMENT REFERENCES

The following specifications, standards, and documents may be used as applicable in the preparation of electrical and electronic drawings:

- a. KSC-E-165 Fabrication of Electrical Ground Support Equipment.
- b. KSC-E-166 Installation of Electrical Ground Support Equipment.
- c. KSC-W-151 Solderless Wrap Process, Electrical Connections, Specification for.
- d. KSC-SPEC-E-0002 Enclosures, Modular, Radio Frequency Interference Shielded, Specification for.

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- e. KSC-W-167 Wiring Programming System Patchboards, Procedure for.
- f. KSC-S-178 Printed Circuit Assemblies, Automatic Wave Soldering of, Procedure for.
- g. KSC-STD-132 Potting and Molding Electrical Cable Assembly Terminations.
- h. KSC-STD-140 Bonding and Grounding Standard.
- i. KSC-STD-E-0002 Hazard Proofing of Electrically Energized Equipment, Standard for.
- j. KSC-STD-E-0001 Design of Electrical Control and Monitor Equipment and Panels, Standard for.
- k. KSC-SPEC-Q-0001 Coatings, Conformal, Protective, Environmental, for Printer Circuit Assemblies, Specification for.
- l. KSC-SPEC-E-0012 Heat and Blast Protection Coating Materials for Electrical Cables, Specification for.
- m. KSC-SPEC-E-0001 Specification for Coating, Conformal (Polyurethane), Printed Circuit Assemblies, Procedure for.

INTERFACE CONTROL DRAWINGS

18.1 GENERAL

This section sets forth the requirements and uniform procedures for the preparation, release, and control of Interface Control Drawings generated for the purpose of Interface Control Documentation (ICD).

18.1.1 DEFINITION

An Interface Control Drawing establishes, controls, and maintains physical and/or functional compatibility between participating activities, at a point or area, where a relationship exists between parts, systems, programs, or procedures.

18.2 GENERAL REQUIREMENTS

Requirements to establish prerequisites in the preparation of drawings for ICD's shall include configuration, all interface data applicable to the envelope, mounting and mating of subsystems, complete interface requirements, (i.e., mechanical, electrical, electronic, pneumatic, etc.), and the requirements defined in the following subparagraphs.

18.2.1 AREA IDENTIFICATION

Area identification will establish the particular launch complex (i.e., LC-34, LC-37, LC-39, etc.) and the major facility identifications of each complex (i.e., LOX area, MSS, etc.) that the ICDs will encompass.

18.2.2 TYPE IDENTIFICATION

Definition of the interface requirements are delineated on ICDs identified in the following subparagraphs.

18.2.2.1 Functional

Those interfaces involving the characteristic action of operations of a system or subsystem.

18.2.2.2 Physical

Those interfaces involving the actual contact or space relationship between mating surfaces or proximate hardware.

18.2.2.3 Cable

Those interfaces involving the mating surfaces of electrical cabling between systems or subsystems equipment.



INTERFACE CONTROL DRAWINGS

18.2.3 ICD IDENTIFICATION NUMBER**18.2.3.1 "A" Level ICD Identification Number**

This identification number shall be obtained from the Launch Operations Panel secretariat by the person generating the "A" level ICD.

18.2.3.2 "B" and "C" Level ICD Identification Numbers

The numbering system to be used for the identification of "B" and "C" level ICDs shall follow the standard numbering system used for normal production drawings. These numbers will be assigned on an individual drawing basis by the Engineering Documentation Center (EDC).

18.3 AUTHENTICATION REQUIREMENTS

Requirements for approvals for ICDs vary with their level, and are established by the interfacing parties.

18.4 ICD PACKAGE

The preparation of ICD packages and their constituent drawings shall follow drafting practices and conventions set forth in Section 3 and 4 of this manual and in the following paragraphs. The requirements specified in the following paragraphs shall take preference.

18.5 ICD PACKAGE ARRANGEMENT

An ICD shall be identified by a single drawing identification number and title and will be of one type; Physical, Functional, or Cable as outlined in Paragraph 18.2.2. However, a combination may be used when necessary.

The first sheet in the package is the cover sheet, followed by the general notes and drawing index, except when an "A" size ICD is prepared. The interface control drawings are added to complete the package. Package arrangement shall be as shown in Figures 18.5-1 and 18.5-2.

INTERFACE CONTROL DRAWINGS

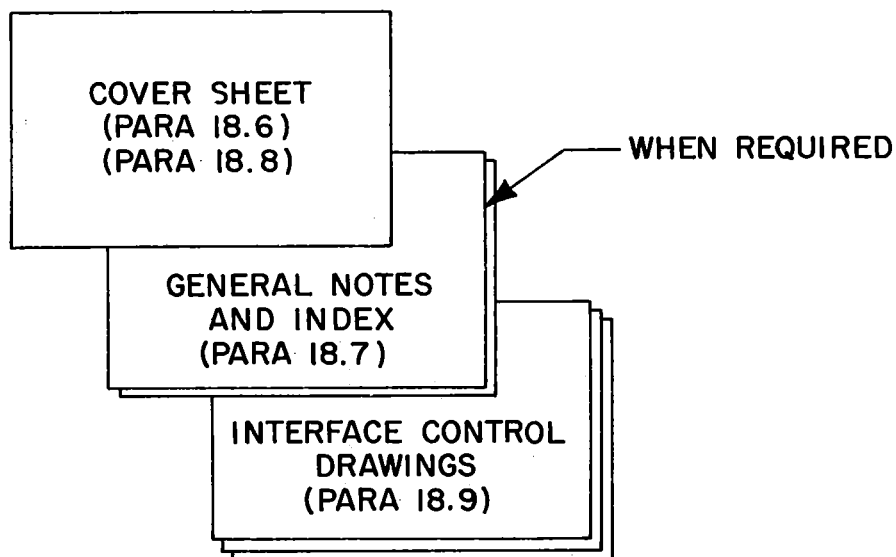


Figure 18.5-1. Typical Package Arrangement Using "B" Size Format and Larger

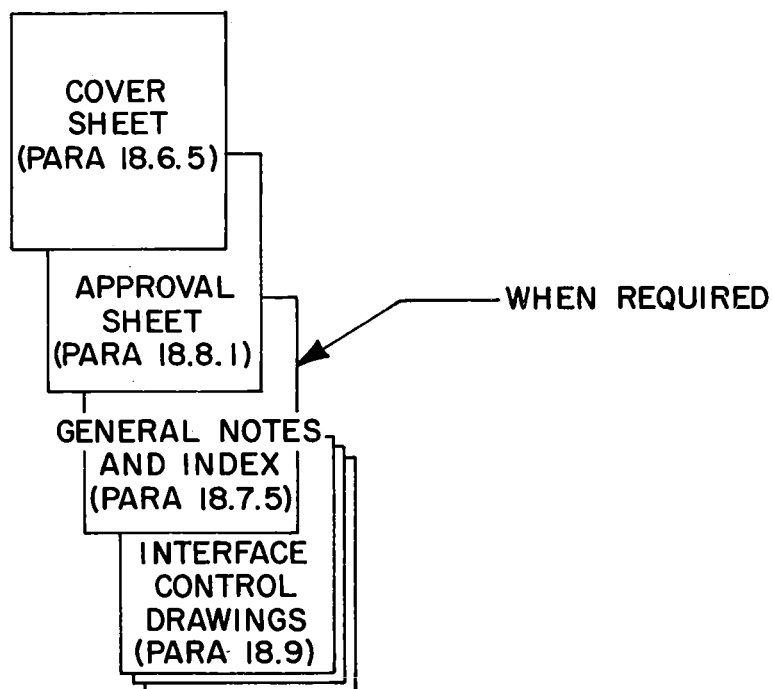


Figure 18.5-2. Typical Package Arrangement Using "A" Size Format

18.5 ICD PACKAGE ARRANGEMENT (Contd)

When the interface information to be recorded is of insufficient quantity to merit the use of the preceding paragraph for package arrangement, the index and general notes, and in some cases the interface information, may be contained on a single sheet, following the requirements of application in this section.

18.5.1 PACKAGE FORMAT

All ICD types referred to herein, shall be prepared on KSC standard formats approved and listed in Section 3. Requirements specified in Section 3 for the completion of the formats shall be adhered to for all interface control drawings.

Physical, Functional, and Cable ICDs shall be prepared on the size format required for proper data presentation. The choice of KSC format shall be no larger than "F" size and shall be constant for the entire package. When an "A" size package is to be prepared, KSC form 21-1 (vertical) shall be used for the cover sheet, and KSC form 21-2B (vertical) shall be used for the remainder of the package content.

18.6 COVER SHEET REQUIREMENTS

Requirements specified in Paragraph 18.8 and the following subparagraphs shall be standard for cover sheets of all ICD packages, other than "A" size which may be used in the preparation of an ICD package as outlined in Paragraph 18.6.6.

18.6.1 PACKAGE TITLE

The title, including the interface package description and its location, shall be positioned in the middle portion of the sheet. When a graphic representation is required, the title will be positioned in the upper middle portion of the cover sheet. Title structure shall be as follows:

- a. The letters shall be black, 1/2-inch high block type, applied by template or facsimile such as Leroy, transfer letters, etc. The method of application desired shall be uniform.
- b. First line -- complex area (Para. 18.2.1).
- c. Second line -- type of interface (Para. 18.2.2).
- d. Third line -- description of facility or interface location.
- e. Fourth line -- description of system, equipment, or other modifiers when required.

INTERFACE CONTROL DRAWINGS

18.6.1 (Contd)

No restriction is placed on the actual number of lines used for the title, but consideration should be given to the amount of space allotted for entry of the title content in the title block of the package drawings (Para. 18.10.2).

18.6.2 GRAPHIC REPRESENTATION OF PACKAGE INTERFACING

A graphic representation, showing points and areas where interfaces are occurring, shall be delineated using the middle portion of the cover sheet. All interfaces shall be located and identified by a method suitable for the individual interface definition (Paragraph 18.10.7.4). Delineation may be in the form of an elevation drawing, a site plan, equipment location, etc., and shall be given a description title, associated with the package title, placed directly under the delineation in 3/8-inch high template letters. Drawing scale shall be noted when applicable.

18.6.3 PHYSICAL PACKAGE

The cover sheet of a Physical ICD package (Figure 18.6-1) shall contain a title and graphic representation when required, adhering to the requirement set forth in paragraphs 18.6.1 and 18.6.2. In addition, the title shall identify the interfacing activities.

18.6.4 CABLE PACKAGE

The cover sheet of a Cable ICD package shall contain a title adhering to the requirements set forth in Paragraph 18.6.1, and in addition, the title shall identify the interfacing activities, such as DE-ESD/DE-MSD, MSFC/KSC, etc., located and defined in Figure 18.6-2.

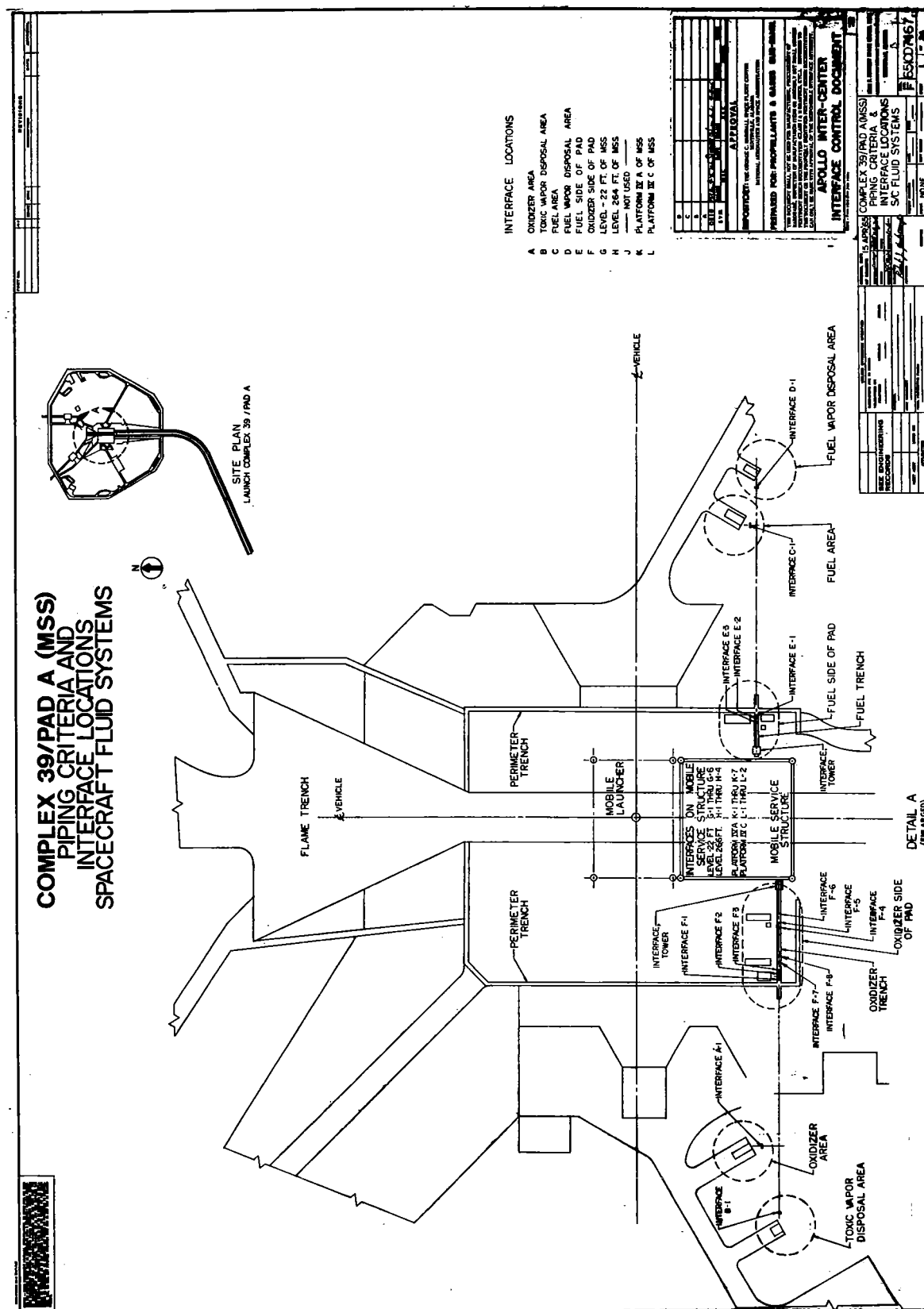
18.6.5 FUNCTIONAL PACKAGE

The cover sheet of a Functional ICD package (Figure 18.6-2) shall contain a title adhering to the requirements in Paragraph 18.6.1. In addition, the title shall identify the interfacing activities.

18.6.6 "A" SIZE PACKAGE

When interface requirements are to be contained within an "A" size document, KSC form 21-2 (vertical) shall be used to prepare "A" size cover sheets (Figure 18.6-3), and contents shall conform to the requirements in the following paragraph.

INTERFACE CONTROL DRAWINGS



**Figure 18.6-1 Sample Cover Sheet for Physical Interface Package
(With Graphic Representation of Interface Definition)**

REVISED

INTERFACE CONTROL DRAWINGS

LAUNCH COMPLEX 34 CABLE INTERFACE PTCS INTERCONNECT DE-ESD/DE-MSD	REVISIONS
	THIS AREA FOR REVISION RECORD ONLY
	APPROVAL DECAL
TITLE BLOCK	

Figure 18.6-2 Sample Cover Sheet for Cable or Functional Interface Package
("B" size format or larger)

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REVISIONS
<p>LAUNCH COMPLEX 34 FUNCTIONAL INTERFACE SPACECRAFT/GSE GASEOUS NITROGEN SYSTEM REQUIREMENTS</p>
DOCUMENT REVISION STATUS BLOCK
TITLE BLOCK

Figure 18.6-3 Sample Cover Sheet for "A" Size Package

REVISED _____

INTERFACE CONTROL DRAWINGS

18.6.6.1 Title

The title, including the interface description and location, shall be positioned in the lower middle portion of the sheet and methods of application shall be as outlined in Paragraph 18.6.1, subparagraphs a, b, c, d, and e, except 1/4-inch high, block type letters shall be used.

18.7 GENERAL NOTES AND INDEX SHEET REQUIREMENTS

General notes and index data may require more than one sheet; however, the index shall always be initially contained on the first sheet.

Requirements specified in the following subparagraphs shall be standard for the applicable "type" of ICD package, other than "A" size, which may be used in the preparation of an ICD package as outlined in Paragraph 18.7.6.

18.7.1 TITLE

The title, "General Notes and Index", shall be applied to each sheet required, in conformance to Paragraph 18.6.1 (a) and shall be positioned in the upper portion of the sheet (Figure 18.7-1).

18.7.2 GENERAL NOTES

Information that may apply to one or more drawings within a package shall be contained on the sheet (s) to avoid repetition (Figure 18.7-1).

The following list is not intended to be all inclusive but to give a sampling of the type of information that may be included.

- a. Applicable notes (Para. 18.10.11).
- b. Symbols and abbreviations not covered by standards (Para. 18.10.8).
- c. Applicable documents.
- d. Requirements.



INTERFACE CONTROL DRAWINGS

GENERAL NOTES AND INDEX (PARA 18.7.1) (PARA 18.7.2)	INDEX <u>SH. NO.</u> <u>DESCRIP.</u> 1 _____ 2 _____ 3 _____ 4 _____ 5 _____ (PARA 18.7.3)	REVISIONS THIS AREA FOR REVISION RECORD ONLY
	TITLE BLOCK	

Figure 18.7-1 Typical General Notes and Drawing Index Sheet
("B" size packages and larger)

INTERFACE CONTROL DRAWINGS

18.7.3 INDEX

The index shall list the sheet number and description of the sheet content. The arrangement shall be as shown in Figure 18.7-1 and conform to the requirements below.

- a. Location of the index on the sheet (s) shall be determined by the draftsman. (Example of placement is shown in Figure 18.7-1.)
- b. The title, "INDEX", shall be underlined. The characters shall be 3/16-inch high and applied by template.
- c. The remainder of the index content shall have characters 1/8-inch high applied by template. The column headings, "SH NO." and "DESCRIPTION", shall be underlined.

18.7.4 PHYSICAL PACKAGE

Requirements specified in Paragraphs 18.7.1, 18.7.2, and 18.7.3 shall apply (Figure 18.7-1).

18.7.5 FUNCTIONAL AND CABLE PACKAGE

The use of a "General Notes and Index" sheet (Figure 18.7-1) may or may not be necessary in the preparation of a Functional or Cable ICD package, depending upon the type of requirement data to be presented. When the inclusion is found necessary, the sheet (s) shall adhere to the requirements in Paragraphs 18.7.1, 18.7.2, and 18.7.3.

18.7.6 "A" SIZE PACKAGE

KSC Form 21-2B (vertical) shall be used to prepare "A" size general notes and index sheets (Figure 18.7-2 and 18.7-3), and contents shall conform to the requirements in the following subparagraphs.

- a. Title

The title shall be positioned in the upper portion of the sheet, and the method of application shall be typewritten characters, upper case.

INTERFACE CONTROL DRAWINGS

CONTINUATION SHEET

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
approximately 2 1/2" for revision records			

GENERAL NOTES
AND INDEX

INDEX

<u>SH. NO.</u>	<u>DESCRIPTION</u>
1 - - - - -	SITE PLAN
2 - - - - -	SPECIFICATIONS
3 - - - - -	OXIDIZER TABLE
4 - - - - -	FUEL TABLE
5 - - - - -	LH ₂ TABLE
6 - - - - -	LOX TABLE
7 - - - - -	HELIUM TABLE
8 - - - - -	WATER-GLYCOL (SS) TABLE AND RCS CHECKOUT TABLE
9 - - - - -	WATER GLYCOL (UT) TABLE
10 - - - - -	OXIDIZER AREA
11 - - - - -	DETAILS
12 - - - - -	TOXIC VAPOR DISPOSAL AREA
13 - - - - -	FUEL AREA
14 - - - - -	DETAILS
15 - - - - -	DETAILS
16 - - - - -	FUEL VAPOR DISPOSAL AREA
17 - - - - -	LOX AREA
18 - - - - -	DETAILS

CODE IDENT NO	DWG SIZE A	
		SHEET

KSC FORM 21-2B (1/64)

Figure 18.7-2 Typical First Sheet of a General Notes and Index for an "A" Size Package



INTERFACE CONTROL DRAWINGS

18.7.6 (Contd)

b. General Notes and Index

The information to be presented shall conform to Paragraphs 18.7.2 and 18.7.3, except the method of application shall be typewritten characters, uppercase.

18.8 APPROVAL SHEET

When a drawing format other than "A" size is used for an ICD package, the cover sheet shall display an approval decal to be used for "A", "B", or "C" level signatures of approval. The decal shall be placed immediately above the title block and as near the right-hand border as possible (Figure 18.8-1).

KSC form decals to be displayed for the applicable "level" approval are listed below, and entries shall be made according to Paragraph 18.10.6.

- a. "A" level - - MSFC Form 1916 (Figure 18.10-5).
- b. "B" level - - KSC Form 21-59 (Figure 18.10-6).
- c. "C" level - - KSC Form 21-60 (Figure 18.10-7).

18.8.1 "A" SIZE APPROVAL SHEET

The approval sheet of an "A" size package shall follow the cover sheet and shall be prepared using KSC Form 21-2B. The applicable "level" approval decal shall be displayed as follows:

- a. "A" level - - Center the decal immediately above the number block (Figure 18.8-2).
- b. "B" and "C" level - - Center the decal, facing to the right, between the number block and revision block as near the right-hand border as possible (Figure 18.8-3).

18.9 INTERFACE CONTROL DRAWING SHEETS

The interface drawings complete the package make-up and shall follow the procedures set forth in Paragraph 18.10 for the delineation and definition of the interface requirements.

INTERFACE CONTROL DRAWINGS

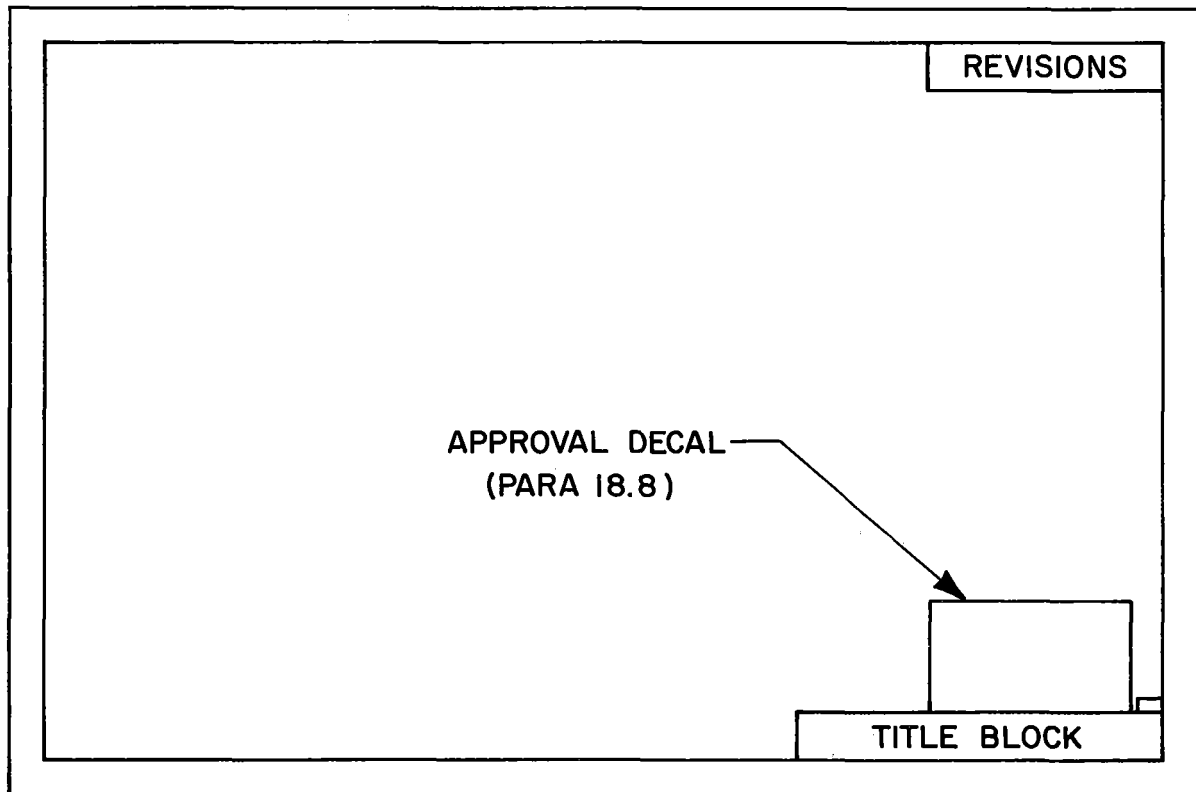


Figure 18.8-1 Cover Sheet with Approval Decal for A,B or C Level Package
("B" Size and larger)



INTERFACE CONTROL DRAWINGS

REVISIONS	
<div>APPROVAL DECAL (PARA 18.8.1a)</div>	
NO. BLOCK	

**Figure 18.8-2 Approval Sheet for "A" Level Package
("A" Size only)**

REVISIONS	
APPROVAL DECAL (PARA 18.8.1b &c)	
NO. BLOCK	

Figure 18.8-3 Approval Sheet for "B" and "C" Level Package ("A" Size Only)



INTERFACE CONTROL DRAWINGS

18.9.1 TITLES

When interfaces within the same package are of more than one system, area, etc., it shall be required to identify, by title, each sheet used for the delineation of each individual system, area, etc. (e.g., LOX area, and LH₂ area).

The title shall be applied in conformance to Paragraph 18.6.1 (a) and shall be positioned in the upper portion of the sheet (s).

18.10 DRAFTING PRACTICES AND ROUTINES**18.10.1 TITLE AND REVISION BLOCK ENTRIES**

Unless otherwise specified by contractor order, the title and revision blocks (Figures 18.10-1, 18.10-2, and 18.10-3) shall be completed conforming to the following instructions. Cross-referencing between the instructions and the pertinent area of the figures is accomplished by means of a number enclosed in a circle, square, or hexagon; e.g., ②. (See Paragraph 18.10.5 for lettering and character heights.)

18.10.1.1 Contractor Entries

- ① Enter date drawing was completed.
- ② Signature of draftsman completing drawing.
- ③ Enter drawing title (per Para. 18.10.2).
- ④ Enter scale of drawing. When not applicable, the word "NONE" shall be entered.
- ⑤ Enter Design Activity Code Identification Number (see Section 7, Para. 7.2).
- ⑥ Enter drawing number assigned by NASA.
- ⑦ Enter applicable sheet number (per Para. 18.10.3).

INTERFACE CONTROL DRAWINGS

APPLICATION		PART NO.	BY	REVISIONS			
NEXT ASSY	USED ON		SYM	DESCRIPTION	DATE	APPROVAL	
			1	1	1	11	1
			5				
			6				
<p>TO BE INITIALED BY NASA AND CONTRACTOR IF REVISED BY CONTRACTOR</p>							
UNLESS OTHERWISE SPECIFIED		ORIGINAL DATE OF DRAWING 1		3		JOHN F. KENNEDY SPACE CENTER, NASA <small>LAUNCH SUPPORT EQUIP. ENGR. DIV. KENNEDY SPACE CENTER, FLORIDA</small>	
DIMENSIONS ARE IN INCHES TOLERANCES ON: FRACTIONS DECIMAL ANGLES		DRAFTER 2 CHECKER 10 TRACER 2 ENGINEER 11					
MATERIAL		SUBMITTED 1					
HEAT TREATMENT		APPROVED 2					
FINAL PROTECTIVE FINISH				SCALE 4	DWG SIZE A	6	
				UNIT WT		SHEET 7 OF	

KSC FORM 21-2 (REV. 9/65)

5 CODE IDENT NO. 22264

Figure 18.10-2 Title and Revision Block for
"A" Size

KSC



MANUAL

Ground Support Equipment

INTERFACE CONTROL DRAWINGS

CONTINUATION SHEET

REVISIONS				
5	SYM	DESCRIPTION	DATE	APPROVAL
6	1	1	1	11 1

TO BE INITIALED BY
NASA AND CONTRACTOR
IF REVISED BY
CONTRACTOR

CODE IDENT NO	DWG SIZE	6
5	A	SHEET 7

Figure 18.10-3 Drawing Number and Revision Block
For "A" Size

INTERFACE CONTROL DRAWINGS

18.10.1.1 Contractor Entries (Contd)

- ⑧ Enter NASA design section symbol.
- ⑨ Enter tolerance when required.

e.g.: Decimals

.xx ± .03 - - indicates 2-place decimal dimensions
shall have ± .03 tolerance unless other-
wise specified.

.xxx ± .010 - - indicates 3-place decimal dimensions
shall have ± .010 tolerance unless
otherwise specified.

Fractions ± 1/32 - - indicates fractional dimensions
shall have ± 1/32 tolerance unless other-
wise specified.

Angles ± 1° or 0° 30' - - as required.

- ⑩ Signature of checker.
- ⑪ Signature of design engineer.

18.10.1.2 NASA Entries

- ① Signature of Technical Supervisor or his designated representative.
- ② Signature of Technical Supervisor or his designated representative.

18.10.1.3 Revision Entries

- ① Enter zone, symbol, description and date (per Para. 18.11.3).
- ⑪ If drawing is revised by contractor, Design Engineer shall initial
change (Para. 18.11.4).

18.10.1.4 Microfilm Entries

- ⑤ All releases that have been microfilmed shall have symbol "F"
entered.
- ⑥ As drawings are changed, released, and microfilmed, the letter
"F" shall be entered adjacent to the latest change.



INTERFACE CONTROL DRAWINGS

18.10.2 DRAWING TITLE

The title block of each sheet of a package shall require an entry in the assigned area. Its contents and structure shall be the same as the package title of the cover sheet and shall adhere to the requirements of Paragraph 18.10.5.

18.10.3 NUMBERING OF SHEETS

Sheets shall be numbered consecutively for the complete package as follows:

First sheet - Sheet 1 of 45
Second sheet - Sheet 2
Third sheet - Sheet 3
Final sheet - Sheet 45 of 45

If a new sheet is added to the package by revision, it shall follow the procedures set forth in Paragraph 18.11.8.2.

18.10.4 DRAWING NUMBERS

The drawing number shall be assigned by the procedures set forth in Paragraph 18.2.3.

18.10.4.1 Letters

Letters used as part of an identification number or drawing number shall be uppercase (capital) letters. In the case of an "A" level number, e.g., 65ICD1234, the letter "I" shall have serifs.

INTERFACE CONTROL DRAWINGS

18.10.5 LETTERING

The style of lettering shall be single-stroke, uppercase gothic except when typewritten characters are used or where standard abbreviations or symbols are used. Character heights for particular items shall be as listed in Figure 18.10-4.

Typewritten characters may be upper and lowercase in gothic or Roman design for "A" size drawings and uppercase gothic only for all other sizes.

18.10.5.1 Size

Preferred character heights for particular items are listed in Figure 18.10-4.

Item	Character Height in Inches for Particular Items*	
	Drawing Sizes A, B, C	Drawing Sizes D, E, F
Drawing number.	1/4	1/4
Drawing title.	3/16	1/4
Drawing subtitle.	1/8	3/16
Letters and numbers used in the body of the drawing.	1/8	5/32
Fractions and Tolerances.	1/8	5/32
Description of Section and Detail views:		
a. "SECTION", "DETAIL"	3/16	3/16
b. "A-A", "B"	1/4	1/4

* Character heights are given for letters made by methods other than machine, i.e., freehand, lettering guide, etc. Typewritten characters shall be 3/32 minimum.

Figure 18.10-4. Character Heights for Particular Items



INTERFACE CONTROL DRAWINGS

18.10.6 APPROVAL DECAL ENTRIES

The approval decal for an "A", "B", or "C" level package (Figure 18.10-5, 18.10-6, and 18.10-7) shall be completed conforming to the following instructions. Cross-referencing between the instructions and the pertinent area of the figures is accomplished by means of a number in a circle or square, e.g., (2)

18.10.6.1 Contractor Entries

- (1) Enter title, assigned by NASA, of responsible Sub-Panel in 3/16-inch high characters by means of template or facsimile. Prefix the pre-printed word "PANEL" with "SUB-".
- (2) Prefix the pre-printed word "APPROVAL" with the NASA Center initials, e.g., "KSC APPROVAL", "MSC APPROVAL", etc.
- (3) Enter the code identification, assigned by NASA, of the responsible KSC Directorate, Division, Branch, or Section that shall be required to apply signatures of approval. Characters shall be entered by means of a template and shall be 1/8 inch in height.

18.10.6.2 NASA Entries

- [1] Signatures of approving NASA personnel (see Para. 18.3).

18.10.6.3 Revisions

Revisions to ICDs must have approval and the approval decal shall require signatures as indicated in paragraph 18.10.6.2 in each space for each revision letter.

INTERFACE CONTROL DRAWINGS

D						
C						
B						
A	I		I		I	
ORIG						
SYM	NAME	DATE	NAME	DATE	NAME	DATE
	MSC		K S C		MSFC	
APPROVAL						
REPOSITORY: THE GEORGE C. MARSHALL SPACE FLIGHT CENTER HUNTSVILLE, ALABAMA NATIONAL AERONAUTICS AND SPACE ADMINISTRATION						
PREPARED FOR:			①	SUB-PANEL		
THIS DOCUMENT SHALL NOT BE USED FOR MANUFACTURING, PROCUREMENT OF HARDWARE, INSPECTION OF MANUFACTURED ITEMS OR ASSEMBLY BUT SHALL GOVERN PERTINENT DESIGN DOCUMENTATION (CLASS I & II DRAWINGS, ETC.). REVISIONS TO THIS DOCUMENT OR THE PROPERLY IDENTIFIED PERTINENT DESIGN DOCUMENTATION CAN ONLY BE MADE WITH APPROVAL OF THE RESPONSIBLE INTERFACE AUTHORITY.						
APOLLO INTER-CENTER INTERFACE CONTROL DOCUMENT						

MSFC - Form 1916 (Rev July 1964)

Figure 18.10-5 Approval Decal "A" Level



INTERFACE CONTROL DRAWINGS

D									
C									
B									
A	1	1	1	1	1	1	1	1	1
ORIG									
SYM	NAME	DATE	NAME	DATE	NAME	DATE	NAME	DATE	DATE
	BRANCH	3	NAME	3	BRANCH	3	NAME	3	DATE
(2) APPROVAL									
REPOSITORY : TECHNICAL INFORMATION CENTER , JOHN F. KENNEDY SPACE CENTER, NASA NOTE: THIS DOCUMENT MAY NOT BE REMOVED FROM THE REPOSITORY WITHOUT THE WRITTEN APPROVAL OF THE DIVISION DIRECTOR.									
THIS DOCUMENT SHALL NOT BE USED FOR MANUFACTURING, PROCUREMENT OF HARDWARE, INSPECTION OF MANUFACTURED ITEMS OR ASSEMBLY BUT SHALL GOVERN PERTINENT DESIGN DOCUMENTATION (CLASS I & II DRAWINGS, ETC.). REVISIONS TO THIS DOCUMENT OR THE PROPERLY IDENTIFIED PERTINENT DESIGN DOCUMENTATION CAN ONLY BE MADE WITH APPROVAL OF THE RESPONSIBLE INTERFACE AUTHORITY.									
APOLLO INTER - DIVISION INTERFACE CONTROL DOCUMENT									

Figure 18.10-6 Approval Decal "B" Level



INTERFACE CONTROL DRAWINGS

D									
C									
B									
A	1	1	1	1	1	1	1	1	1
ORIG									
SYM	NAME	DATE	NAME	DATE	NAME	DATE	NAME	DATE	DATE
	BRANCH	3	BRANCH	3	SECTION	3	SECTION	3	SECTION

(2) APPROVAL

REPOSITORY : TECHNICAL INFORMATION CENTER , JOHN F. KENNEDY SPACE CENTER, NASA

NOTE: THIS DOCUMENT MAY NOT BE REMOVED FROM THE REPOSITORY WITHOUT THE WRITTEN APPROVAL OF THE DIVISION DIRECTOR.

THIS DOCUMENT SHALL NOT BE USED FOR MANUFACTURING, PROCUREMENT OF HARDWARE, INSPECTION OF MANUFACTURED ITEMS OR ASSEMBLY BUT SHALL GOVERN PERTINENT DESIGN DOCUMENTATION (CLASS I & II DRAWINGS, ETC.). REVISIONS TO THIS DOCUMENT OR THE PROPERLY IDENTIFIED PERTINENT DESIGN DOCUMENTATION CAN ONLY BE MADE WITH APPROVAL OF THE RESPONSIBLE INTERFACE AUTHORITY.

**APOLLO INTRA - DIVISION
INTERFACE CONTROL DOCUMENT**

Figure 18.10-7 Approval Decal "C" Level



INTERFACE CONTROL DRAWINGS

18.10.7 DELINEATION IDENTIFICATION REQUIREMENTS

The requirements for lettering and line characteristics apply when delineating symbols for sections, views, detail views, scale, etc. The following subparagraphs set forth symbols and methods that shall be used for delineation identification.

18.10.7.1 Sections

A section shall be identified as shown in Figure 18.10-8. Single identifying letters assigned in alphabetical sequence shall be used to identify sections, views, and detail views. (Para 18.10.5) Do not use letters I, O, and Q. In cases where single letters of the alphabet are exhausted multiple letters may be used, e.g., AA, BB, etc.

In no case shall a section or view of the same drawing carry the same identifying letter. If Section A exists, there shall be no View A or Detail View A. In cases where complete delineation of more than one interfaced system, area, etc., may be required within a single ICD package, (Para 18.9.1) letters used to identify sections and views may be used more than once within a package, but one time only within a titled interface delineation.

When a section is cut on one sheet of a drawing and delineated on another, cross-referencing of sheet numbers shall be required, but shall not be required when the delineation is contained on the same sheet.

- a. Identifying letters and sheet numbers shall be shown by means of a horizontally divided 5/8-inch balloon. The upper half of the balloon shall contain the letter that identifies the delineation. The lower half of the balloon shall contain the sheet number. Adjacent to the lower half of the balloon shall be placed the zone location (Figure 18.10-8).

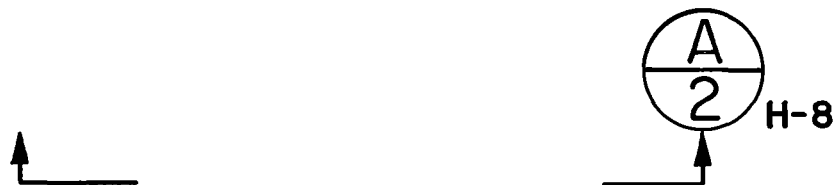
18.10.7.2 Views

A view shall be identified as shown in Figure 18.10-9. The same restrictions with respect to the use of identifying letters and the balloon identification for sections, shall apply.

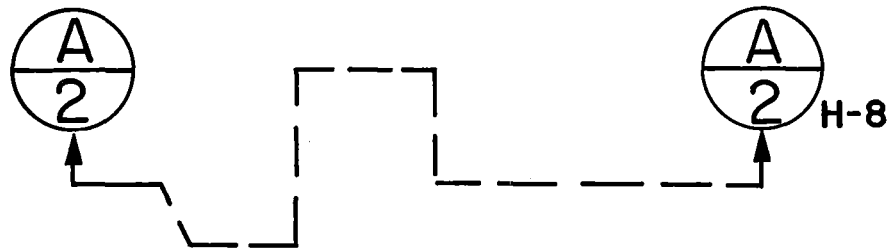
18.10.7.3 Detail Views

A detail view shall be identified as shown in Figure 18.10-10. The same restrictions with respect to the use of identifying letters and the balloon identification for sections, shall apply.

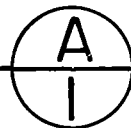
INTERFACE CONTROL DRAWINGS



(a) SIMPLE CUTTING PLANE



(b) OFFSET CUTTING PLANE

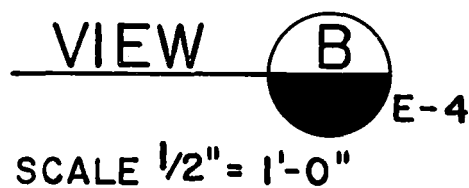
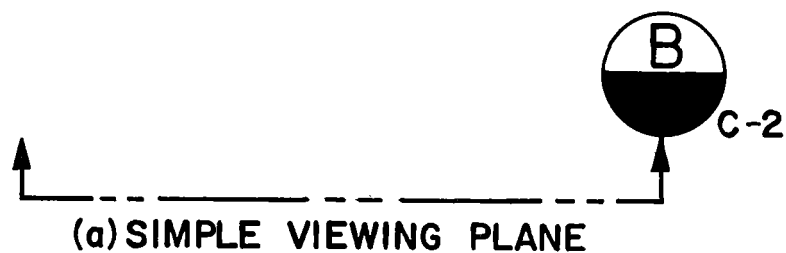
SECTION 

ROTATED 45° CW
SCALE $\frac{1}{2}" = 1'-0"$
200' $4\frac{1}{8}"$ LEVEL

(c) SECTION DELINEATION IDENTIFICATION

Figure 18.10-8 Example of Section Identification

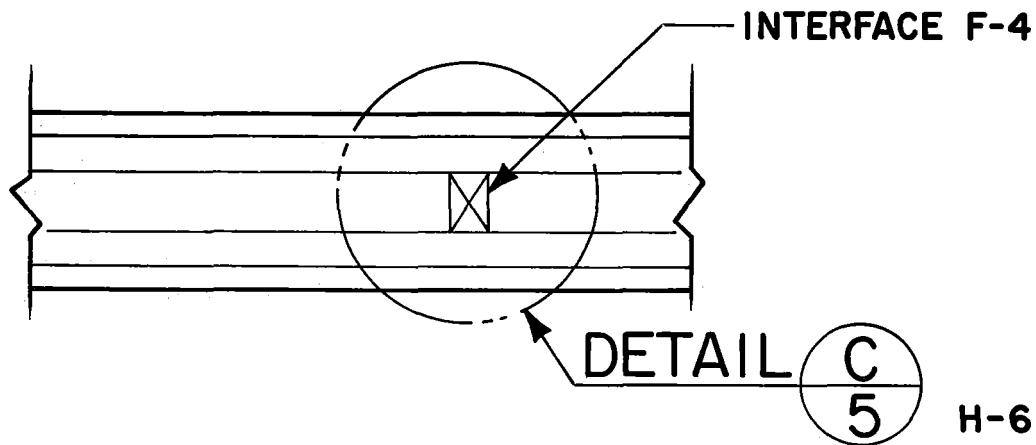
INTERFACE CONTROL DRAWINGS



(c) VIEW DELINEATION IDENTIFICATION

Figure 18.10-9 Example of View Identification

INTERFACE CONTROL DRAWINGS



(a) DETAIL VIEW LOCATION



ENLARGED
INTERFACE F-4
(OXIDIZER VAPOR DISPOSAL UNIT)

(b) DETAIL VIEW DELINEATION IDENTIFICATION

Figure 18.10-10 Example of Detail View Identification

INTERFACE CONTROL DRAWINGS

18.10.7.4 Interfaces

Identification of a point where a relationship exists between responsible activities shall be as shown in Figure 18.10-11. The symbol illustrated shall be used in the manner applicable to the type of delineation required to describe the interface.

- a. Figure 18.10-11a - - Identifies the interface within a fluid system, such as LH₂, LOX, etc., delineated by means of a single line schematic or block diagram.
- b. Figure 18.10-11b - - Identifies the interface points within an area, such as LH₂, LOX, etc., delineated by means of a plan view.
- c. Figure 18.10-11c - - Identifies electrical interfaces within equipment delineated by means of an interconnection diagram.

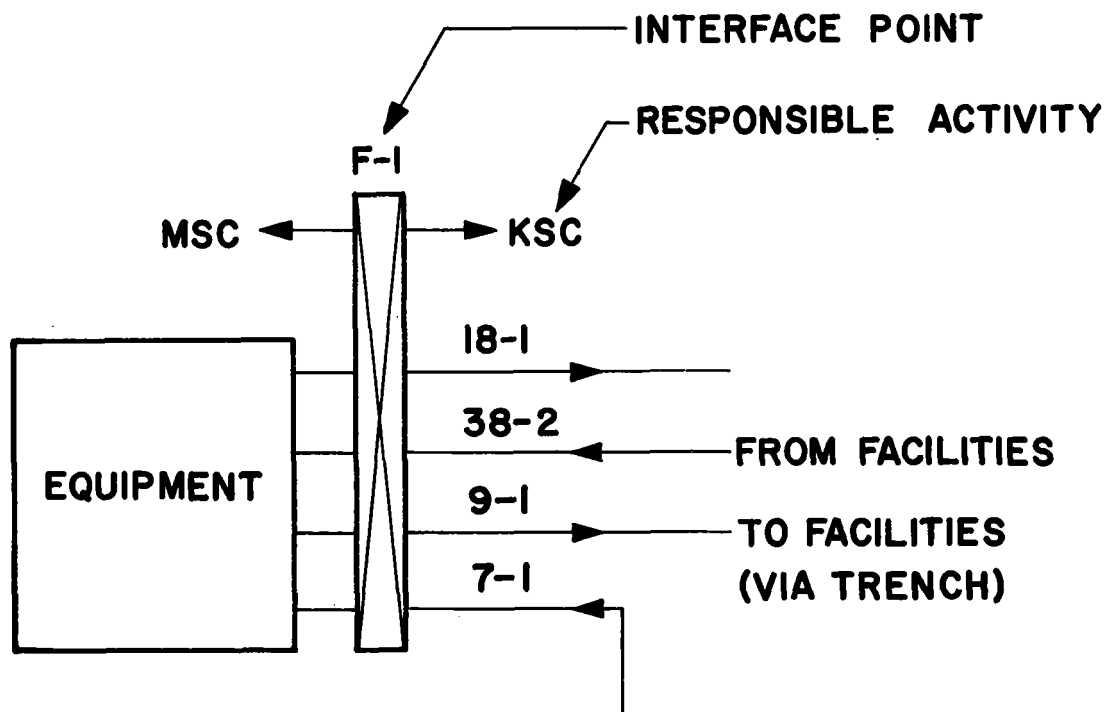


Figure 18.10-11a Single Line Schematic or Block Diagram

INTERFACE CONTROL DRAWINGS

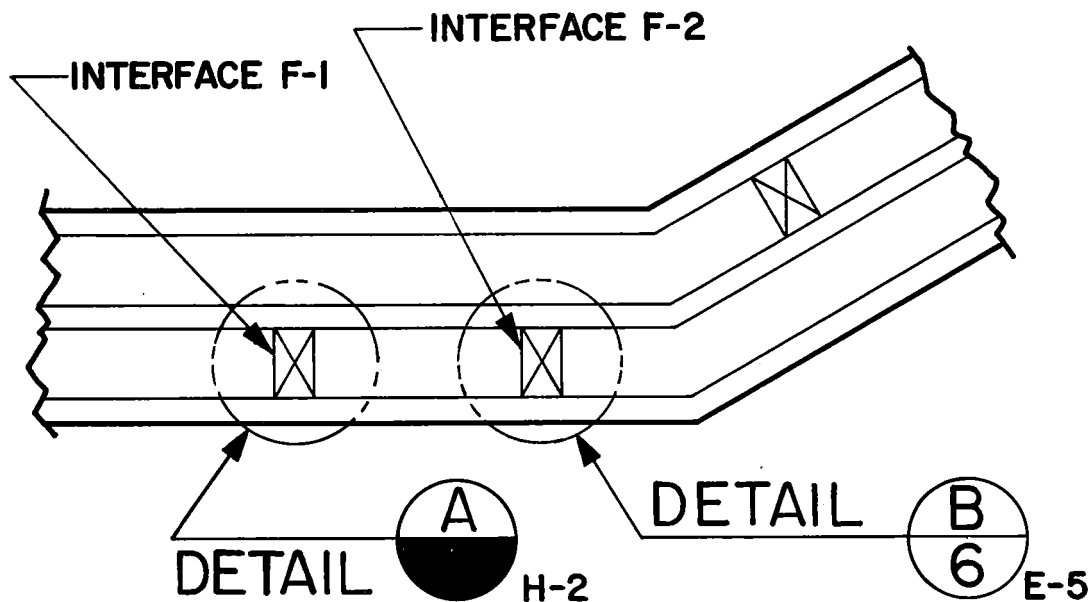


Figure 18.10-11b Partial Plan View

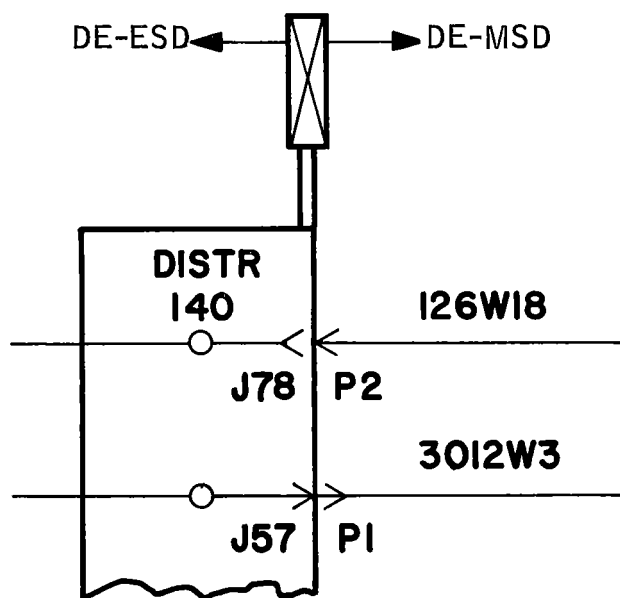


Figure 18.10-11c Cable Interconnection Diagram

INTERFACE CONTROL DRAWINGS

18.10.8 SYMBOLS

The use of symbols shall meet the requirements of this Section and Section 14. Symbols used that do not conform to these requirements shall be legended on the General Notes and Index sheet when the use is evident throughout the entire ICD package. When the symbols are used on only one or two drawing sheets, they may be legended on the applicable sheets.

18.10.9 DIMENSIONING AND TOLERANCING

Dimensioning and tolerancing shall be in accordance with Section 5.

18.10.10 NORTH ARROW

All drawings showing a plan view shall have a standard north arrow placed adjacent to the view and shall be as shown in Figure 18.10-12.



Figure 18.10-12 Standard North Arrow

To maintain a uniform and consistent presentation, the plan view should, if possible, be located to permit the north direction to be at the top of the sheet.

18.10.11 NOTES

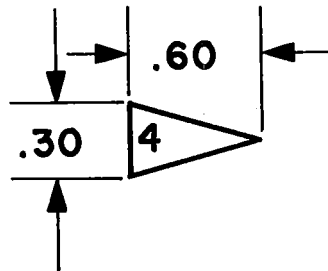
18.10.11.1 General Notes

Notes of general character, that do not require leaders to indicate where they apply, and are applicable throughout an ICD package shall be grouped together and placed on the General Notes and Index sheet of the package.

INTERFACE CONTROL DRAWINGS

18.10.11.2 Specific Notes

Specific notes apply to specific views, details, or requirements. These notes should be placed on the particular sheet to which they apply, but they may be included with the general notes. (Para 18.10.11.1) In either case a specific note shall be referenced by placing the note number within a triangular flag located on the sheet where the note applies. The specific note in the group of notes shall also have its note number placed within a triangular flag. The size of the triangular flag shall be:



INTERFACE CONTROL DRAWINGS

18.11 REVISIONS**18.11.1 INTERFACE REVISION NOTICE (IRN)**

Revisions to ICDs are documented by IRN. The IRN Forms and the detailed procedures for IRN processing are contained in "Engineering Procedures" document, KD1A0133.

ICD's must be changed to incorporate IRNs when either of the following exists:

- a. A maximum of six IRNs are outstanding against an ICD package.
- b. An IRN has been outstanding for ninety days.

18.11.1.1 IRN Identification Number

IRN identification numbers are assigned by the responsible "level" activity which controls the ICD.

18.11.2 REVISION IDENTIFICATION

Revisions to an ICD package are recorded in the "Revision Block" of the drawings and shall be identified by the use of revision letter symbols, change suffix numbers and zone identification.

18.11.2.1 Revision Letter Symbols

Revision letter symbols shall be uppercase, 3/16-inch high characters, starting with "A" and advancing in alphabetical sequence each time the drawing is revised. The letters "I", "O", "Q", and "X" shall not be used. When revisions are numerous enough to exhaust the alphabet, the revisions following the letter "Z" shall be lettered "AA", the next "AB", etc., the next sequence shall be "BA", "BB", etc. (See Para. 18.11.3.1a).

INTERFACE CONTROL DRAWINGS

18.11.2.2 Change Suffix Numbers

A suffix number shall start with "(1)" and advance in numerical sequence in parenthesis, identifying each change incorporated by an IRN for each REVISION LETTER SYMBOL. (See Para. 18.11.3.1b)

18.11.3 REVISION BLOCK

Each revision shall be recorded in the revision block, adhering to the requirements of Paragraphs 18.11.3.1 and 18.11.8 at the time the drawings of the ICD are changed. (Figures 18.11-1 and 18.11-3)

18.11.3.1 Requirements

- a. Revision letter symbols, in accordance with Paragraph 18.11.2.1, identifying each drawing revision shall be noted in the "SYM" column.
- b. A revision shall be noted in the "DESCRIPTION" column with the appropriate suffix number for each individual change made. (See Para. 18.11.2.2) When changes are extensive in nature or number and it is impractical to record all the items of the revision, the term "General Change See IRN _____" may be used, when authorized.
- c. The use of abbreviations may be used per Section 13.
- d. Pictorial sketches and symbology shall not be used.
- e. Lettering shall be neat, legible, and a height of 1/8 inch.

18.11.4 REVISION APPROVAL

The initials and/or signatures of the persons checking and approving the revision (Para. 18.10.1) shall appear in the "Approved" column and the date that they are entered shall appear in the "Date" column. Signatures, initials, and dates shall be entered in reproducible ink. (Figure 18.11-1)

18.11.5 REVISIONS SPECIFIED BY IRN

The field of the drawing shall be revised in accordance with items described on the IRN. The IRN number and the itemized changes shall be recorded in the "Description" column (Figure 18.11-1). More than one IRN may be incorporated under the same revision letter symbol at the time of change. (Figure 18.11-1, Rev. B)

K S C



MANUAL

Ground Support Equipment

INTERFACE CONTROL DRAWINGS

REVISIONS				
ZONE	SYM	DESCRIPTION	DATE	APPROVAL
E-4	A	R1 (1) ADDED VIEW C (2) DELETED LINE 8-1	Feb. 4 1965	J. Smith KDP. P.R.S.
E-6 D-2	B	R2 (1) ADDED NOTES 1, 2 & 3 (2) .03 WAS .02 AT VIEW C R3B (1) DELETE NOTE 3 (2) 4.70 WAS 4.20 IN SEC A	Mar. 10 1965	J. Smith KDP. P.R.S.
C-6 D-5	C	R4 (1) ADDED SECTION D CHANGED LOCATION OF VIEW C	July 8 1965	K. Jones C.R.K. P.R.S.
	D	BY DIRECT REVISION CORRECTED SPELLING ERROR IN NOTE 1	July 9 1965	K. Jones C.R.K. P.R.S.
	E	R5A GENERAL CHANGE SEE IRN	July 14 1965	J. Smith KDP. P.R.S.

EXPLANATION

Revision A -- Indicates two specific changes per IRN (para 18.11.3.1b)

Revision B -- Indicates the incorporation of two outstanding IRN's at the same time. (para 18.11.1b)

Revision C -- Indicates one specific change per IRN and a change not specified by IRN (Direct revision) (para 18.11.6.2)

Revision D -- Indicates a direct revision (para 18.11.6.1)

Revision E -- Indicates a general change (para 18.11.3.1b)

Figure 18.11-1. Typical Revision Block

REVISED _____

INTERFACE CONTROL DRAWINGS

18.11.6 REVISIONS NOT SPECIFIED BY IRN

When the decision by properly designated individuals has been made that an IRN is not required, changes may be made by "Direct Revision". When changes are made by direct revision (Figure 18.11-1, Rev. D), the revision letter symbol shall be advanced and the change recorded in the revision block. Revision approval, per Paragraph 18.11.4, shall apply.

18.11.6.1 Direct Revision

Changes which may be made by direct revision are as follows:

- a. Change location of views or notes.
- b. Change of number of sheets on drawing.
- c. Addition of information to Revision Status Block.
- d. Retrace or redraw - no other change.
- e. Change in title.
- f. Correction of spelling error, when the interpretation remains the same.

18.11.6.2 IRN and Direct Revision

Incorporation of IRN's and direct revisions may be entered in the revision block under the same revision letter symbol. IRN's should be listed first. (Figure 18.11-1, Rev. C)

18.11.7 ORIGINAL DRAWING RENEWAL

18.11.7.1 Photographed - - No change

When a new original without change is made by any photographic process, and legibility is satisfactory without further retouching, no revision record shall be required.

18.11.7.2 Redrawn or Photographed and Retouched

When a new original is made by redrawing manually or by photographic methods which required retouching, the revision letter shall be advanced and a statement placed in the "DESCRIPTION" column as shown in Figure 18.11-2.



 INTERFACE CONTROL DRAWINGS

REVISIONS				
ZONE	SYM	DESCRIPTION	DATE	APPROVAL
	F	REDRAWN - NO CHANGE	Aug 20, 1964	J. Smith DS

Figure 18.11-2 Sample Revision Block Showing Drawing Redrawn - - No Change.

18.11.7.3 Redrawn and Revised

When a new original is made by redrawing manually or by photographic methods and a change is made, the revision letter shall be advanced. The word redrawn shall be entered in the description column, and the changes recorded in accordance with change procedures outlined in Paragraph 18.11.3.

18.11.8 REVISION STATUS

The ICD package shall have the latest revision letter to any sheet recorded on the cover sheet. The last revision letter on the cover sheet will be the latest revision to the entire ICD package, regardless of the number of sheets. (Figure 18.11-3)

A suitable entry shall be made in the revision block of the cover sheet to record revisions to other sheets within the package, in addition to those that may be made to the cover sheet. (Figure 18.11-4)

18.11.8.1 Revision Letter Assignment

All changes that take place at the same time on one or more sheets of an ICD package shall be identified by the same revision letter symbol. The revision letter to be used for a change on any sheet will be the next higher letter, in sequence with those recorded on the cover sheet. (Figure 18.11-3)

18.11.8.2 Adding New Sheets

When adding new sheets, a revision letter shall be recorded in the revision column of the new sheets (s). The applied revision letter will be the same letter that caused the addition of the sheets. The statement "Sheet Added" shall be recorded in the description column with the initiating IRN, if required, specified in the normal manner.

INTERFACE CONTROL DRAWINGS

18.11.8.3 Revision Status Block

A tabulated "Revision Status Block" shall be drawn above the title block of the cover sheet as shown in Figure 18.11-3 and Figure 18.6-4 for "A" size application. The current revision letter of each sheet shall be recorded and sequentially updated for each revision.

KSC



MANUAL

Ground Support Equipment

INTERFACE CONTROL DRAWINGS

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
A			
D			

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
B			
C			

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
A			
B			
C			
D			
E			

Para. 18.11.8

(SEE FIGURE 18.11-4)

(COVER SHEET)

Para. 18.11.8.3

REVISION STATUS OF SHEETS					DOC. REV.
		D	C	E	REV
		3	2	1	SH

1/4 INCH SQUARE

ALL 1/8 INCH HIGH CHARACTERS

APPROVAL DECAL

SHEET 1 OF 3

SHEET 2

SHEET 3

Figure 18.11-3 Package Revision Status

INTERFACE CONTROL DRAWINGS

REVISIONS					
ZONE	SYM	DESCRIPTION		DATE	APPROVAL
	A	R1	REVISED SHEET 3	Feb. 4 1965	F. Smith CDR.
		R2A	REVISED SHEET 2	Mar 10 1965	
	B	R3	(I) DWG NO. 65ICD	July 8 1965	K. Jones CDR. P.R.S.
			WAS 66ICD. REVISED SHEET 2		
	C	R4B	REVISED SHEET 3	July 9 1965	K. Jones CDR. P.R.S.
	D	BY DIRECT REVISION CORRECTED SPELLING ERROR IN TITLE		July 14 1965	F. Smith OKJ

EXPLANATION

- Revision A -- Indicates IRN-R1 incorporated on Sheet 3.
- Revision A -- Indicates IRN-R2A incorporated on Sheet 2.
- Revision B -- Indicates IRN-R3 incorporated on Sheet 1 and 2.
- Revision C -- Indicates IRN-R4B incorporated on Sheet 3.
- Revision D -- Indicates direct revision to Sheet 1.

Figure 18.11-4 Typical Cover Sheet Revision Status Record.
 (Applicable to A, B, or C Level ICD's)

DRAWING CHECKING

19.1 GENERAL

This section contains guidelines for the inspection and checking of engineering drawings and associated lists. The information presented herein is not comprehensive, and these points are not the only ones to be considered in inspecting drawings. Experience has shown that these items are usually the most troublesome and, therefore, require a formal check.

19.2 DRAWING INSPECTION AND CHECKING

The following subparagraphs define the items which should be inspected and checked as applicable, prior to issuing new and revised drawings.

19.2.1 QUALITY

- a. General appearance.
- b. Line density and spacing (see Section 4).
- c. All arrowheads shown.
- d. Lettering proper size and not crowded (see Section 4).
- e. All erasures and corrections are properly made (see Section 10).
- f. Drawing material undamaged.

19.2.2 TITLE BLOCK (SEE SECTION 4)

- a. Code identification number entered.
- b. Title correct.
- c. Sheet numbering correct.
- d. Size and drawing number properly entered.
- e. Scale shown.
- f. Material specified.

DRAWING CHECKING

19.2.2 (Contd)

- g. Tolerances shown.
- h. Dates correctly entered.
- i. Required approval signatures.
- j. "Next assembly" and "used on" properly entered.

19.2.3 DRAWING PRACTICES

- a. Notes correctly located and information conveyed is clear (see Section 4).
- b. Abbreviations correct (see Section 13).
- c. Spelling correct.
- d. All items and/or assemblies identified (see Section 7).
- e. Symbology correct (see Section 14).
- f. Security classification and note properly located (see Section 3).

19.2.4 PARTS LIST

- a. Item find numbers correspond to those on assembly drawing (see Section 4).
- b. Identification of each item (see Section 4).
- c. Nomenclature of each item (see Section 6).
- d. Quantity of each item, either a definite quantity, or AR, or REF.

19.2.5 RUNNING LISTS

- a. List number correct.
- b. Sheet numbers correct.
- c. Issue date entered.

DRAWING CHECKING

19.2.5 (Contd)

- d. "Called for on" drawing number entered.
- e. "Made for" nomenclature entered.
- f. Item number correct.
- g. Wire and sleeve identification.
- h. Terminal parts list items.
- i. "To" and "from" connectors.
- j. "Shield of" entered.
- k. Notes, remarks, and routing correct.

19.2.6 ELECTRICAL SCHEMATIC (SEE SECTION 17)

- a. All components have reference designations.
- b. All symbols per Section 14.

19.2.7 CONTROL DRAWINGS (SEE SECTION 2)

- a. Adequate delineation or description to inspect part.
- b. Outline dimensions.
- c. Mounting dimensions.
- d. Part numbers or tabulation.
- e. Vendor name and address.
- f. Material.
- g. Finish.
- h. Parts marking note.



DRAWING CHECKING

- i. Electrical or mechanical requirements.
- j. Environmental requirements.

19.2.7.1 Specification Control Drawing.

- a. Vendor part number.
- b. Specification control drawing note located correctly.

19.2.7.2 Source Control Drawing

- a. Vendor part number.
- b. Source control drawing note located correctly.

19.2.7.3 Altered Part Drawing

- a. Alterations to outline.
- b. Alterations to dimensions.
- c. Alterations to finish or material.
- d. Alteration to vendor part number.
- e. Altered part drawing note located correctly.

19.2.8 MISCELLEANOUS

- a. Pattern references on casting drawings (see Section 29).
- b. Die references on die casting, forging or molded part drawings (see Section 27).
- c. Inspection requirements (radiographic, magnetic particle, etc) (see Sections 27 and 29).
- d. Dissimilar metal protection (see Section 9).
- e. Reference to "Drawing Terms and Tolerances" (see Section 25).



DRAWING CHECKING

19.2.8 (Contd)

- f. Surface finish (see Section 8).
- g. Use of flags in referring to specific notes (see Section 4).
- h. Geometric symbols (see Section 5).
- i. Tooling points and/or tooling locations (see Section 29).
- j. Revision block correctly prepared (see Section 10).

TUBING, PIPE, AND FITTINGS

20.1 GENERAL

This section contains a list of known current KSC standards and specifications covering materials, parts, and fabrication of tubing and piping assemblies. It is intended as a ready reference only and is not to be construed as authority for use of any document listed herein on any existing contract.

20.1.1 ADDITIONAL MATERIAL

Additional material will be included in this section as specific needs are identified.

20.2 REFERENCE LIST

- | | | |
|----|-----------------|---|
| a. | KSC-F-124 | Fittings (Pressure Connections), Flared Tube, Specification for. |
| b. | KSC-C-123 | Cleanliness Levels, Cleaning, Protection, and Inspection Procedures for Parts, Field Parts, Assemblies, Subsystems, and Systems for Fluid Use in Support Equipment. |
| c. | KSC-SPEC-Z-0007 | Tubing, Steel, Corrosion Resistant, Types 304 and 316, Seamless, Annealed, Specification for. |
| d. | KSC-SPEC-Z-0008 | Specification for Fabrication and Installation of Tube Assemblies and Installation of Fittings and Fitting Assemblies. |
| e. | KSC-SPEC-Z-0001 | Specification for Pipe, 36% Nickel, Iron-Base (Invar 36) |
| f. | KSC-GP-425 | Engineering Standards (KC Fittings) |

WELDING, BRAZING AND SOLDERING

21.1 DEFINITIONS

This paragraph contains brief explanations of standard welding terms and definitions. The terms are presented to establish standard nomenclature and definitions for expressions related to welding and applied processes.

Base Metal - The metal to be welded.

Filler Metal - Metal to be added in making a weld. Filler material shall conform to prescribed welding specification.

Welding Process - A metal-joining process wherein coalescence is produced by heating to suitable temperature with or without the application of pressure and with or without the use of filler metals. Welding process shall conform to the prescribed welding specification.

Gas Metal - Arc Welding (Mig) - An arc-welding process wherein coalescence is produced by heating with an electric arc between a filler metal (consumable) electrode and the work. Shielding is obtained from a gas, a gas mixture (which may contain an inert gas), or a mixture of a gas and a flux.

Gas Tungsten - Arc Welding (Tig) - An arc-welding process wherein coalescence is produced by heating with an electric arc between a single tungsten (nonconsumable) electrode and the work. Shielding is obtained from a gas or gas mixture (which may contain an inert gas).

Atomic Hydrogen Welding - An arc-welding process wherein coalescence is produced by heating with an electric arc maintained between two metal electrodes in an atmosphere of hydrogen. Shielding is provided by the hydrogen.

Resistance Welding - A group of welding processes wherein coalescence is produced by the heat obtained from resistance of the work to the flow of electric current in a circuit of which the work is a part, and by the application of pressure.

Brazing - A group of welding processes wherein coalescence is produced by heating to suitable temperatures above 800° F and by using a nonferrous filler metal, having a melting point below that of the base metals. The filler metal is distributed between the closely fitted surfaces of the joint by capillary attraction. The two commonly used filler metals are copper and silver alloys.

Joint Preparation - The machined preparation of the welded joint prior to welding. Joint preparation shall be in accordance with the prescribed welding specification.



WELDING, BRAZING AND SOLDERING

21.1 (Contd)

Procedure Qualification - The demonstration that welds, made by a specific procedure, can meet the prescribed standards. Qualification shall conform to prescribed welding specifications.

Quality Assurance - Assurance that the strength, workmanship, and quality of the weld meets the prescribed welding specifications.

21.2 WELDING SYMBOLS

This paragraph presents the basic weld symbols and types of weld by which members are frequently joined.

21.2.1 BASIC ARC AND GAS WELD SYMBOLS

Fillet	Plug or Slot	Arc-Spot or Arc-Seam	Groove				
			Square	V	Bevel	U	J

Groove		Back or Backing	Melt-Thru	Sur-facing	Flange Edge	Flange Corner
Flare V	Flare Bevel					

21.2.2 BASIC RESISTANCE WELD SYMBOLS

Type of Weld			
Resistance Spot	Projection	Resistance Seam	Flash or Upset

21.2.3 SUPPLEMENTARY SYMBOLS

Weld All Around	Field Weld	Contour	
		Flush	Convex



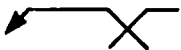



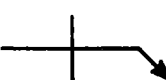
WELDING, BRAZING AND SOLDERING

ARC AND GAS WELD SYMBOLS							
Location Significance	Groove						
	Square	V	Bevel	U	J	Flare-V	Flare-Bevel
Arrow-Side							
Other-Side							
Both-Sides							
No Arrow-Side or Other-Side Significance	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used

ARC AND GAS WELD SYMBOLS								
Location Significance	Fillet	Plug Or Slot	Arc-Seam or Arc-Spot	Back Or Backing	Melt-Thru	Surfacing	Flange	
							Edge	Corner
Arrow-Side				Groove Weld Symbol 	Groove or Flange Weld Symbol 	Not Used		
Other-Side				Groove Weld Symbol 	Groove or Flange Weld Symbol 	Not Used		
Both-Sides		Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used
No Arrow-Side Or Other-Side Significance	Not Used	Not Used	Not Used	Not Used	Not Used		Not Used	Not Used

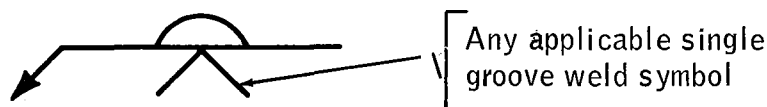
WELDING, BRAZING AND SOLDERING

21.2.6 RESISTANCE WELD SYMBOLS

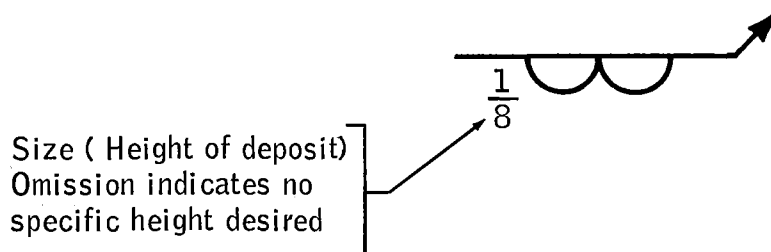
Location Significance	Resistance Weld Symbols			
	Resistance Spot	Projection	Resistance-Seam	Flash or Upset
Arrow-Side	Not Used		Not Used	Not Used
Other-Side	Not Used		Not Used	Not Used
Both-Sides	Not Used	Not Used	Not Used	Not Used
No Arrow-Side or Other-Side Significance		Not Used		

21.2.7 TYPICAL BUILT-UP WELDING SYMBOLS

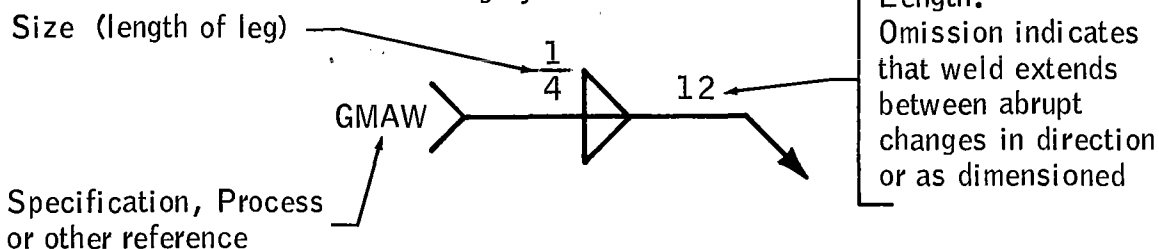
a. Back or backing weld symbol



b. Surfacing weld symbol indicating built-up surfaces - Orientation, Location and all dimensions other than size are shown on the drawing.



c. Double-fillet welding symbol

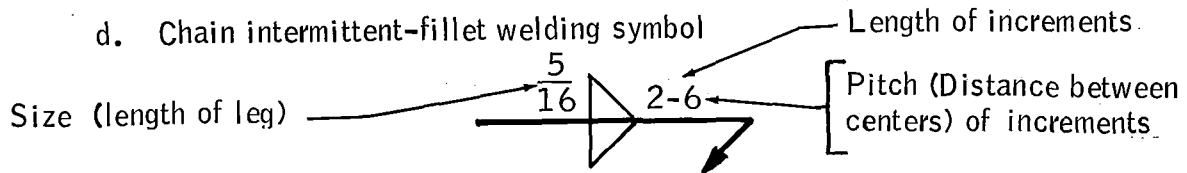




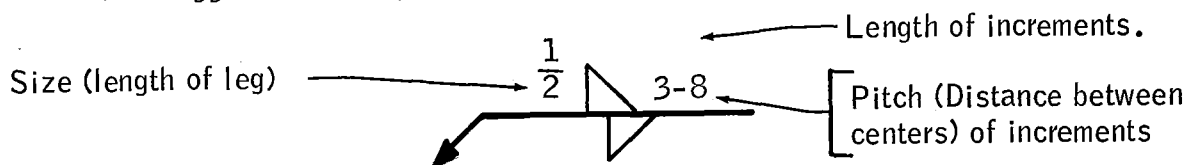
WELDING, BRAZING AND SOLDERING

21.2.7 (Contd)

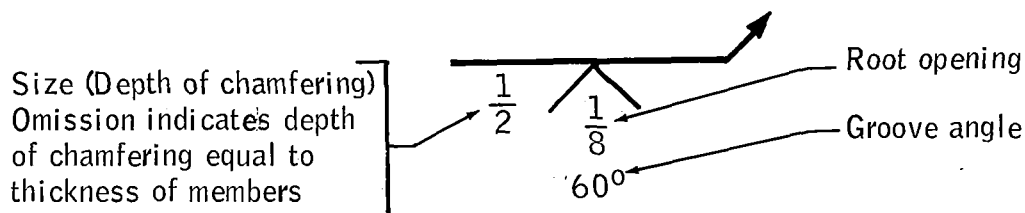
d. Chain intermittent-fillet welding symbol



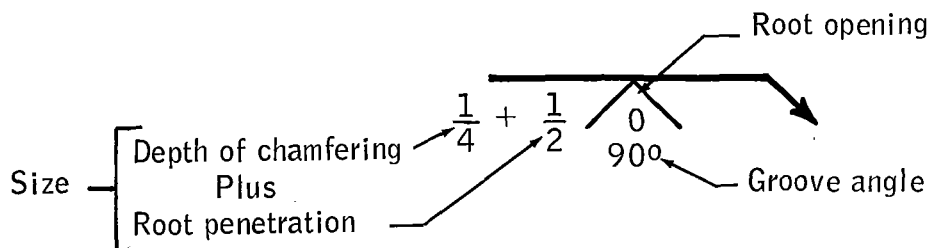
e. Staggered intermittent-fillet welding symbol



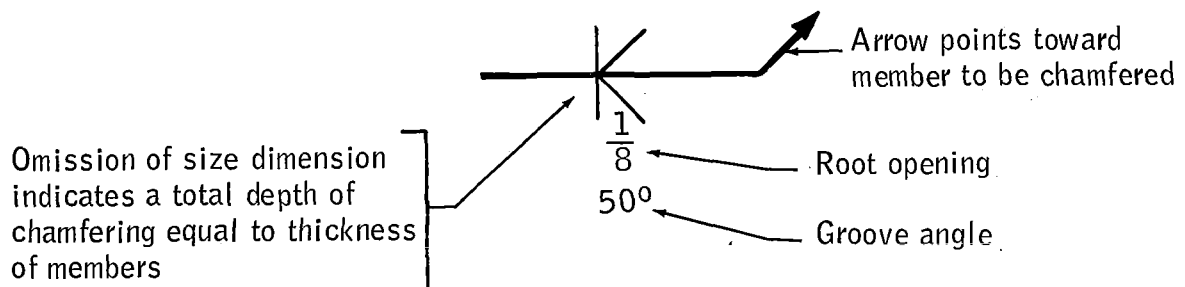
f. Single-V groove welding symbol



g. Single-V groove welding symbol indicating root penetration



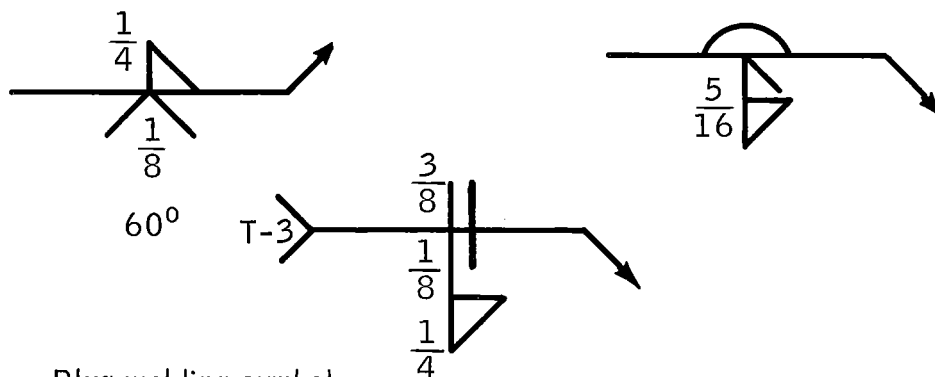
h. Double-bevel groove welding symbol



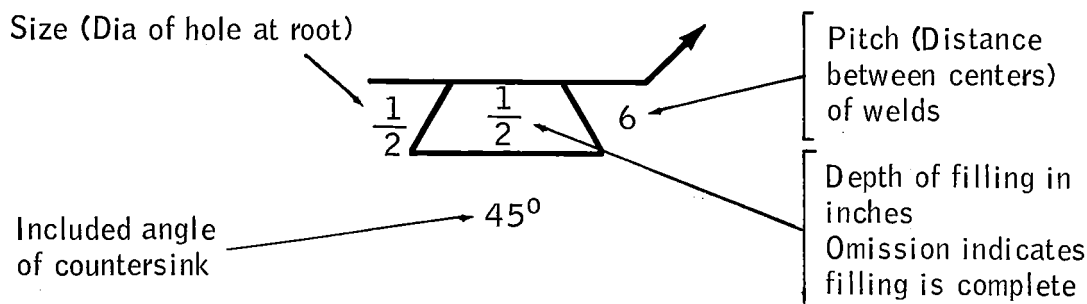
WELDING, BRAZING AND SOLDERING

21.2.7 (Contd)

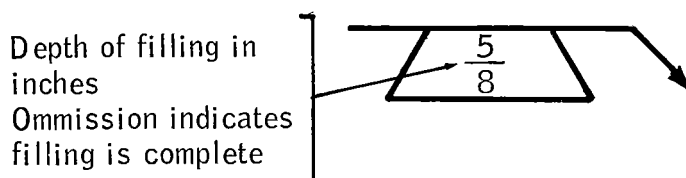
i. Welding symbols for combined welds



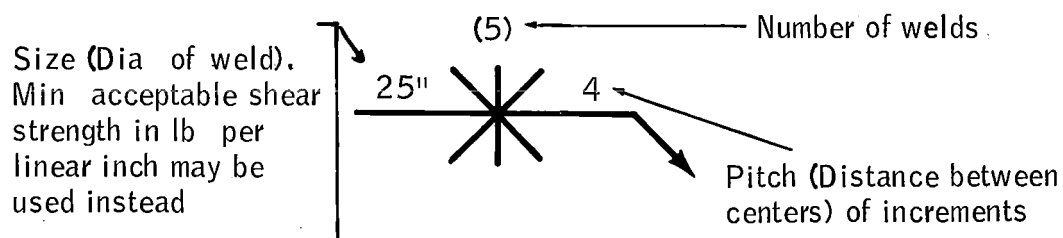
j. Plug welding symbol



k. Slot welding symbol - Orientation, Location and all dimensions other than depth of filling are shown on the drawing



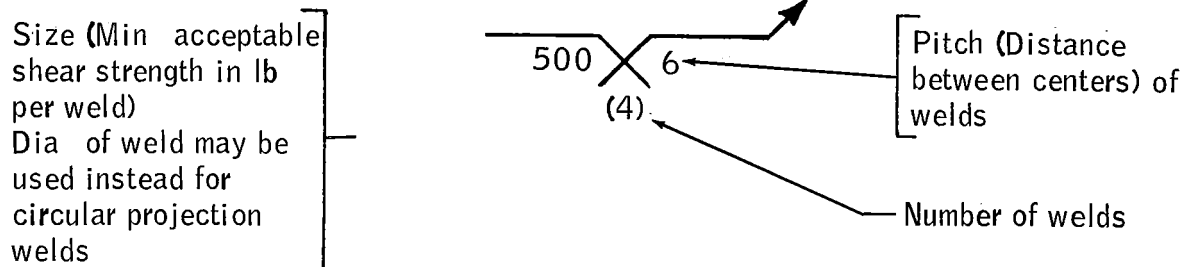
l. Resistance-spot welding symbol



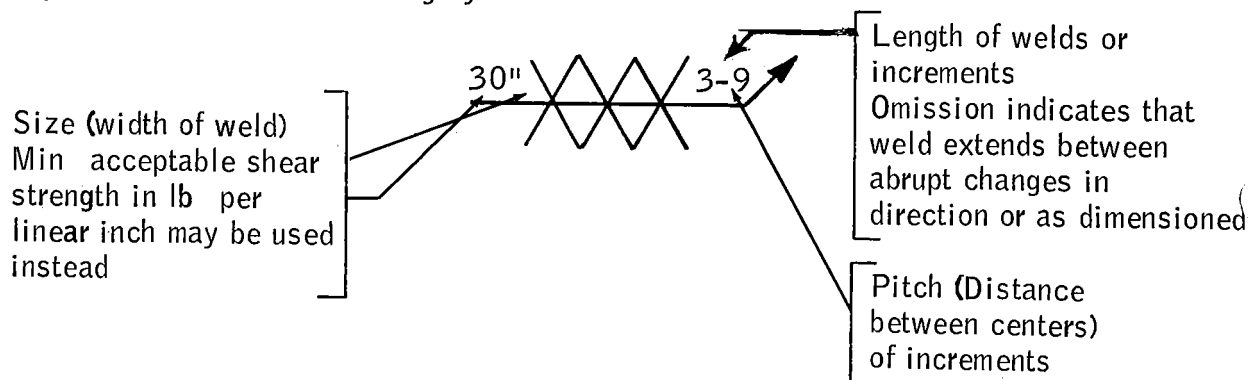
WELDING, BRAZING AND SOLDERING

21.2.7 (Contd)

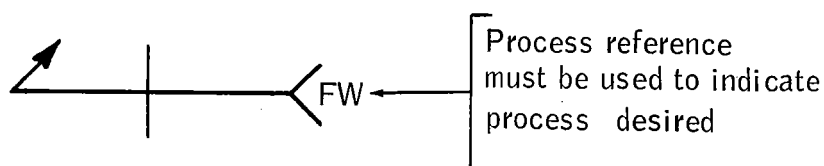
m. Projection welding symbol



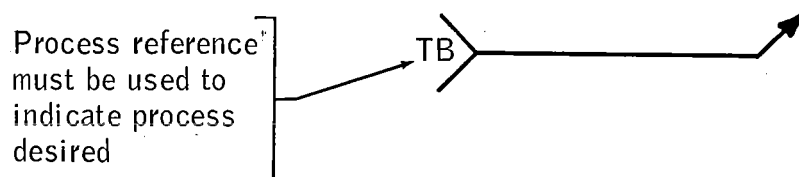
n. Resistance-seam welding symbol



o. Flash or upset welding symbol



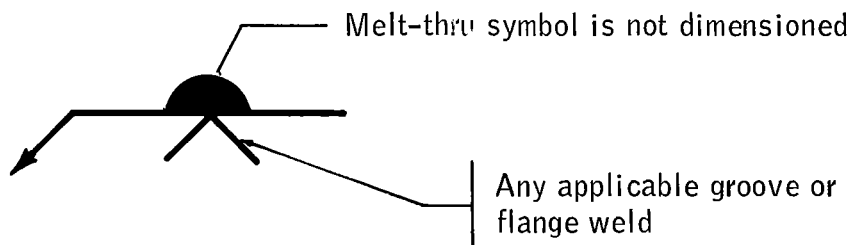
p. Brazing, forge, thermit, induction, and flow welding symbol



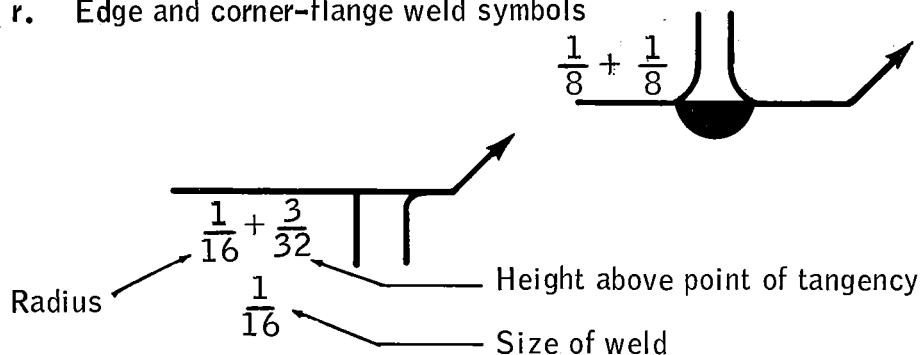
WELDING, BRAZING AND SOLDERING

21.2.7 (Contd)

q. Melt-through weld symbol

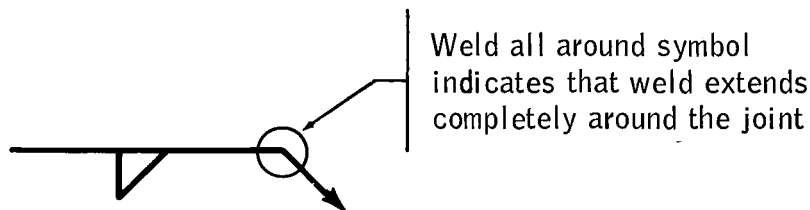


r. Edge and corner-flange weld symbols

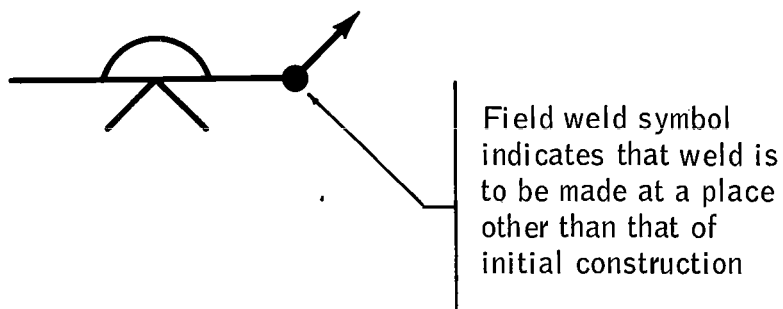


21.2.8 SUPPLEMENTARY SYMBOLS

a. Weld-all-around symbol



b. Field weld symbol

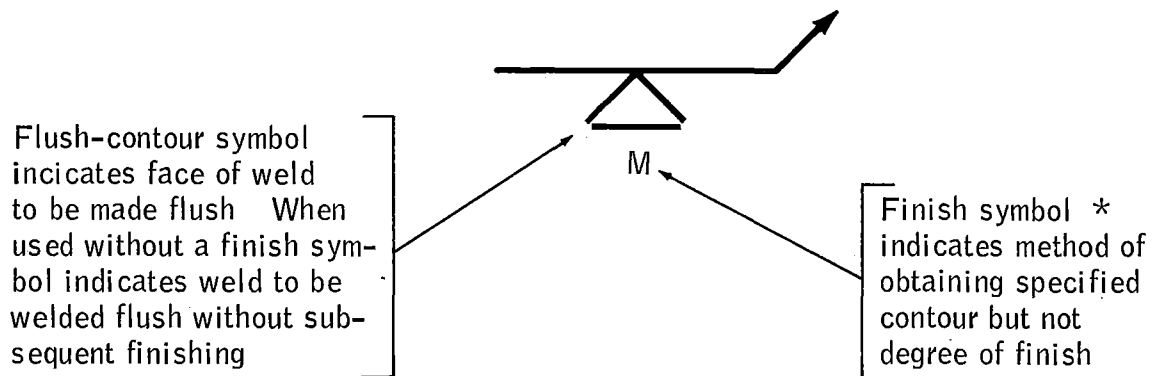




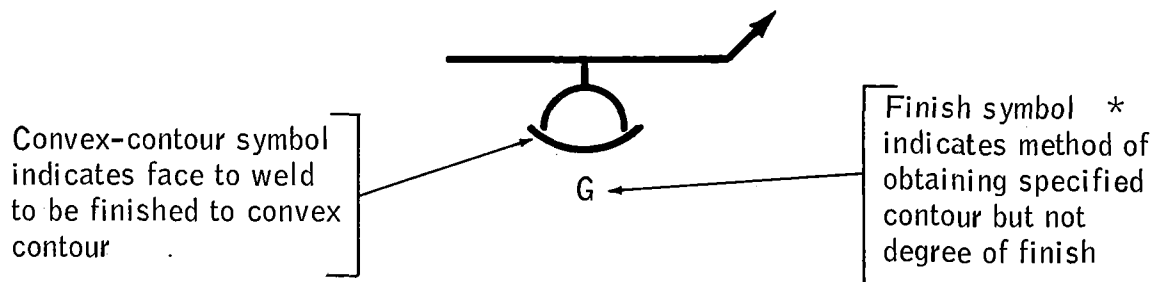
WELDING, BRAZING AND SOLDERING

21.2.8 (Contd)

c. Flush-contour symbol



d. Convex-contour symbol



* Finish Symbols
 C=Chipping
 G=Grinding
 M=Machining

WELDING, BRAZING AND SOLDERING

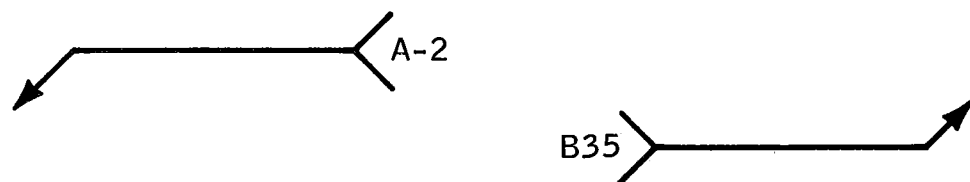
21.3 DRAFTING PRACTICE

Welding symbols provide the means of placing complete welding information on engineering drawings. All symbols presented in this paragraph conform with standards established by the American Welding Society. Correct use of the proper symbols will aid in maintaining control of strength, costs, and processes.

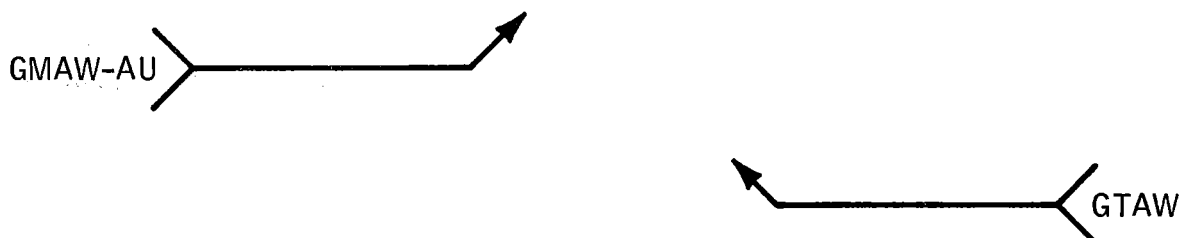
In addition to the symbols listed in paragraph 21.2 the following supplementary information and examples will effect uniform presentation of all welding requirements by this activity.

21.3.1 LOCATION OF SPECIFICATION, PROCESS, OR OTHER REFERENCES

- a. When a specification, process, or other reference is used with a welding symbol, the reference shall be placed in the tail, thus:



- b. When the use of a definite process is required, the process may be indicated by one or more of the letter designations shown in Table 21-1.





WELDING, BRAZING AND SOLDERING

21.3.2 USE OF SYMBOLS WITHOUT REFERENCES

When desired, symbols may be used without specification, process, or other references in the following instances:

- a. When a note such as the following appears on the drawing:
"UNLESS OTHERWISE DESIGNATED, ALL WELDS ARE TO BE MADE IN ACCORDANCE WITH SPECIFICATION NO. _____."
- b. When the welding procedure to be used is prescribed elsewhere.

21.3.3 USE OF GENERAL NOTES

When desired, general notes such as the following may be placed on a drawing to provide detailed information pertaining to the predominating welds, and this information need not be repeated on the symbols. "UNLESS OTHERWISE INDICATED, ALL FILLET WELDS ARE 5/16 INCH SIZE." "UNLESS OTHERWISE INDICATED, ROOT OPENINGS FOR ALL GROVE WELDS ARE 3/16 INCH."

Table 21-1

Designation of Welding Process by Letters

	WELDING PROCESS	LETTER DESIGNATION See Note 1
Brazing	Torch Brazing	TB
	Furnace Brazing	FB
	Induction Brazing	IB
Resistance Welding	Projection Weld	Letter designations have not been assigned to spot and projection welding since the weld symbols used are adequate.
	Spot Weld	
Arc Welding	Gas-Tungsten-Arc Welding	GTAW
	Gas Metal-Arc Welding	GMAW
	Atomic Hydrogen Welding	AHW
Note 1 - Letter designations for processes not listed shall comply with American Welding Society, Welding Handbook, Section One.		

WELDING, BRAZING AND SOLDERING

21.3.3 (Contd)

The following suffixes may be used, if desired, to indicate the method of applying the above processes:

Automatic Welding	AU
Machine Welding	ME
Manual Welding	MA
Semi-Automatic Welding	SA

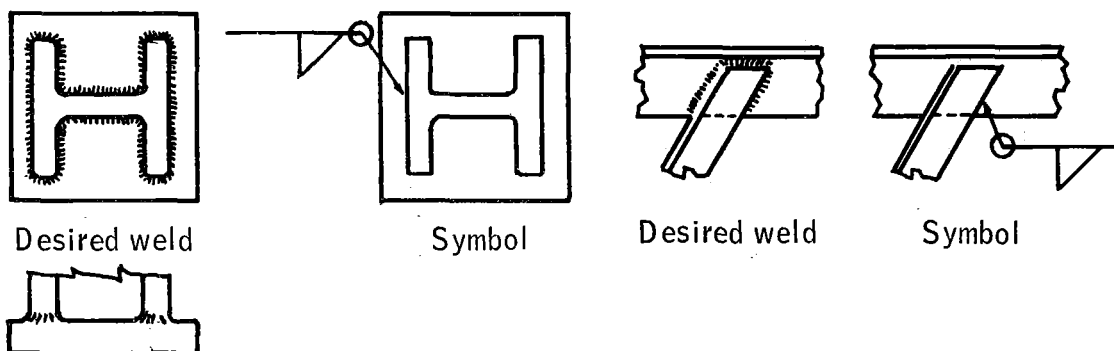
When no specification, process, or other reference is used with a welding symbol, the tail may be omitted, thus:



21.3.4 USE OF WELD-ALL-AROUND SYMBOL

Welds extending completely around a joint shall be indicated by means of the all-around symbol, thus:

Weld All-around Symbol

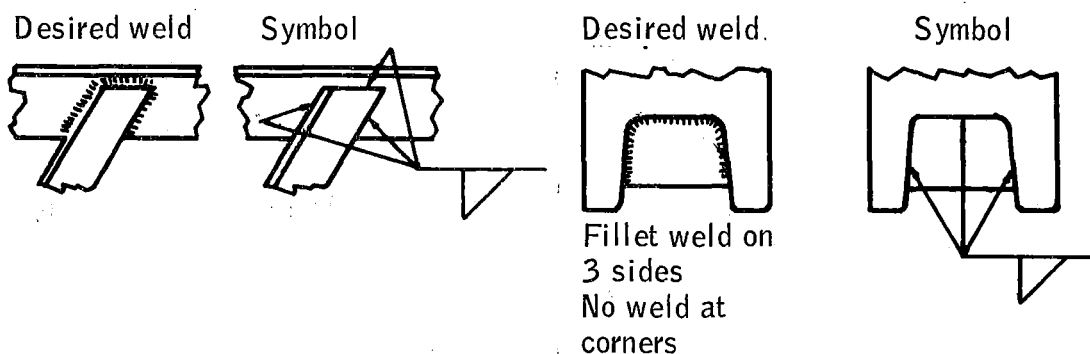




WELDING, BRAZING AND SOLDERING

21.3.5 EXTENT OF WELDING DENOTED BY SYMBOLS

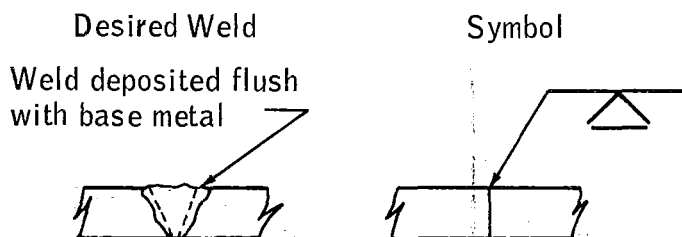
Symbols apply between abrupt changes in the direction of the welding or to the extent of hatching or dimension lines, except when the weld-all-around symbol is used.



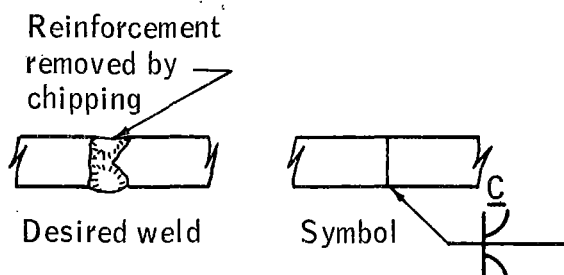
21.3.6 FINISHING OF WELDS

Finishing of welds, when required, shall be indicated by suitable contour and finish symbols.

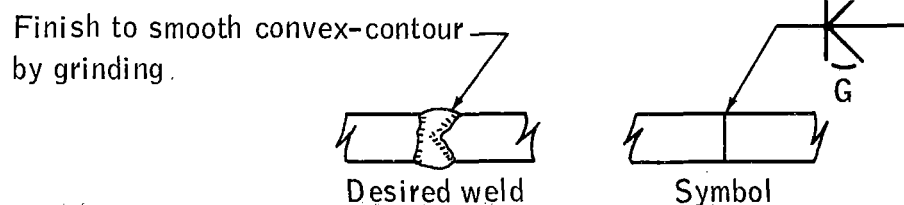
a. Arrow-side flush-contour symbol



b. Other-side flush-contour symbol



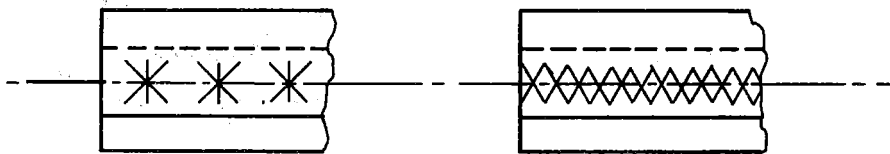
c. Both-sides convex-contour symbol



WELDING, BRAZING AND SOLDERING

21.3.7 LOCATION OF WELD SYMBOLS

- a. Weld symbols, except resistance-spot and resistance-seam, shall be shown only on the welding symbol reference line and not on the lines of the drawing.
- b. Resistance-spot and resistance-seam weld symbols may be placed directly on the drawings at the locations of the desired welds, thus:



21.3.8 CONSTRUCTION OF SYMBOLS

■ Fillet, bevel- and J-groove, flare-bevel-groove, and corner-flange weld symbols shall be shown with the perpendicular leg always to the left.

21.3.9 COMBINED WELD SYMBOLS

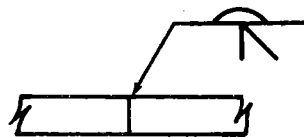
For joints having more than one weld, a symbol shall be shown for each weld, thus:

- a. Single-bevel-groove and back or backing weld symbols

Desired weld

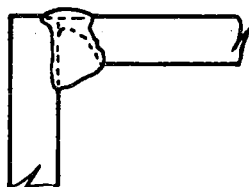


Symbol

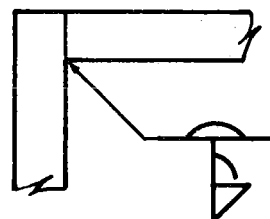


- b. Back or backing, single-J-groove, and fillet weld symbols

Desired weld



Symbol

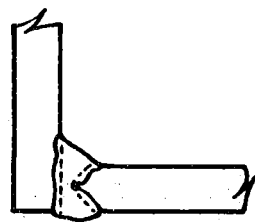




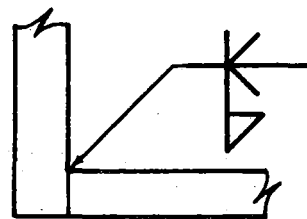
21.3.9 (Contd)

c. Fillet and double-bevel-groove weld symbols

Desired weld

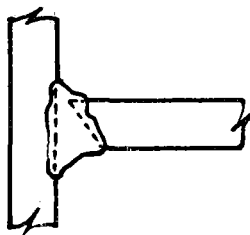


Symbol

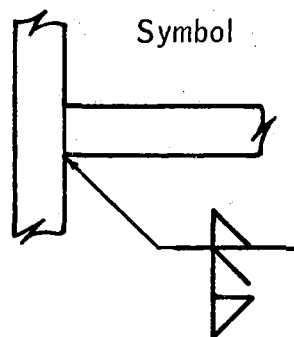


d. Single-bevel-groove and double-fillet weld symbols

Desired weld

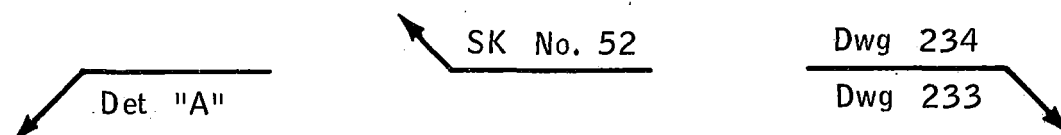


Symbol



21.3.10 DESIGNATION OF SPECIAL TYPES OF WELDS

When the basic weld symbols are inadequate to indicate the desired weld, the weld shall be shown by a cross section, detail, or other data, with a reference thereto on the welding symbol, observing the usual location significance; thus:



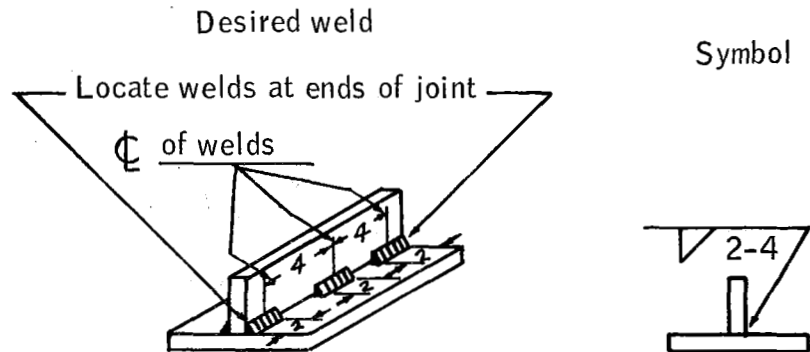
21.3.11 DIMENSIONING OF INTERMITTENT FILLET WELDING

The pitch (center-to-center spacing) of intermittent fillet welding shall be shown to the right of the length dimension.

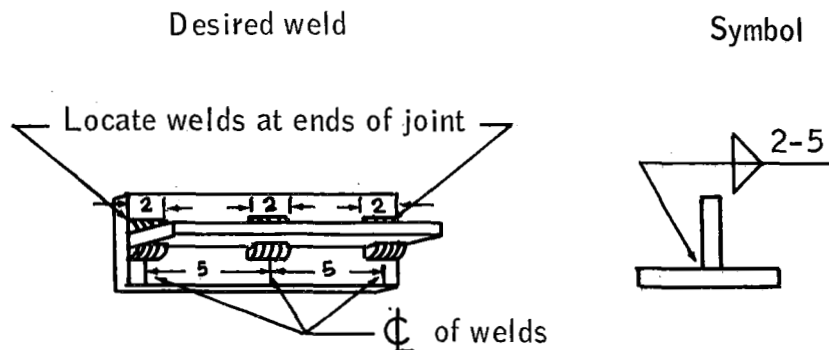
WELDING, BRAZING AND SOLDERING

21.3.11 (Contd)

a. Length and pitch of increments of intermittent welding



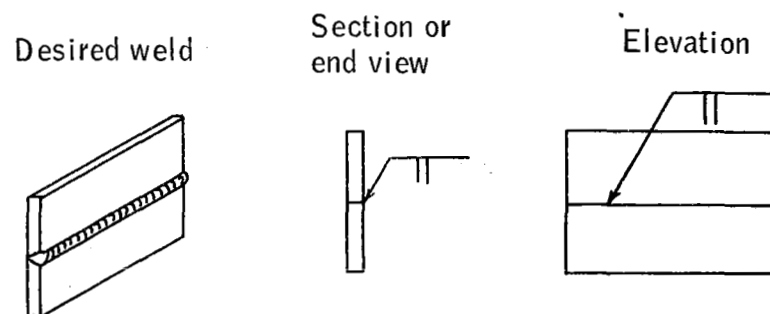
b. Length and pitch of increments of chain intermittent welding



21.3.12 GROOVE WELDING

21.3.12.1 Application of Square-Groove Welding Symbol

a. Arrow-side square-groove welding symbol

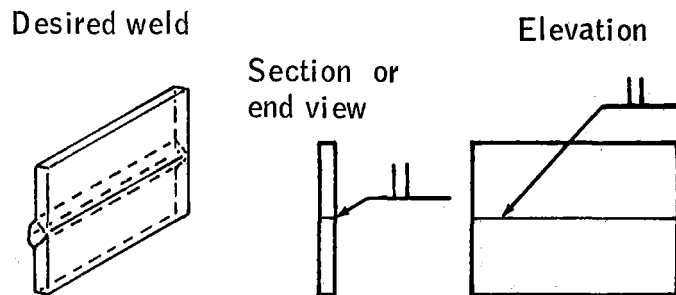




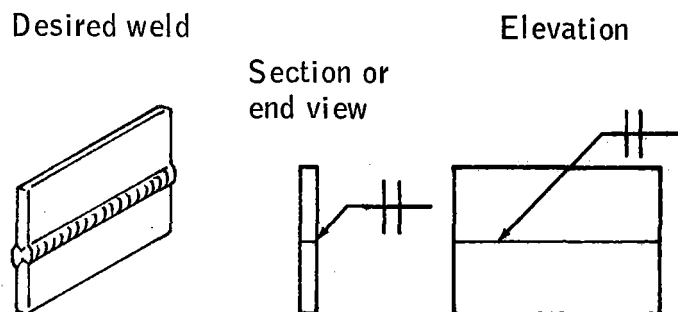
WELDING, BRAZING AND SOLDERING

21.3.12.1 (Contd)

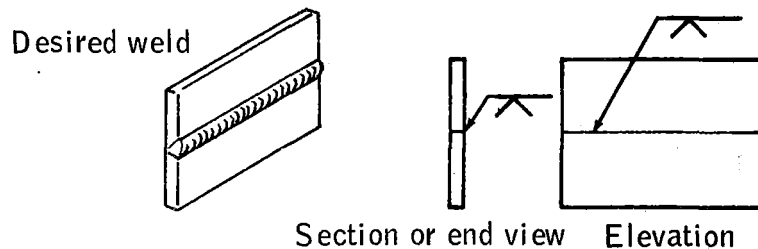
b. Other-side square-groove welding symbol



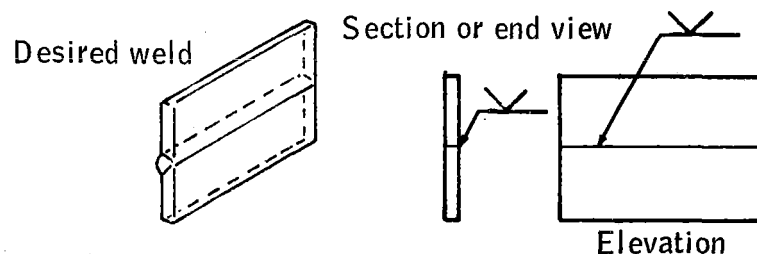
c. Both-sides square-groove welding symbol

21.3.12.2 Application of V-Groove Welding Symbol

a. Arrow-side V-groove welding symbol



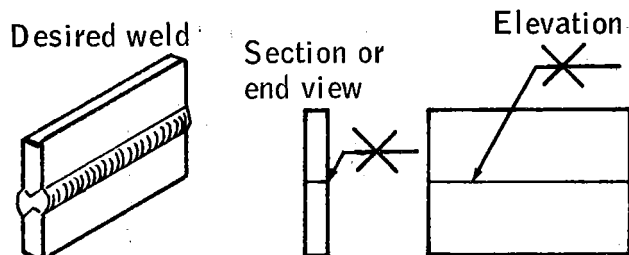
b. Other-side V-groove welding symbol



WELDING, BRAZING AND SOLDERING

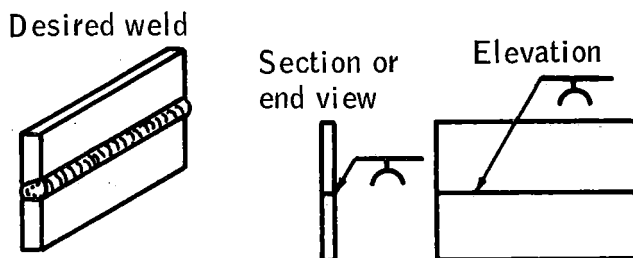
21.3.12.2 (Contd)

c. Both-sides V-groove welding symbol

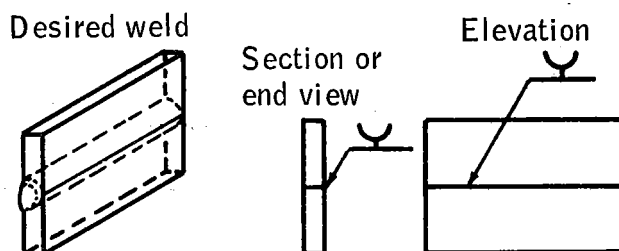


21.3.12.3 Application of U-Groove Welding Symbol

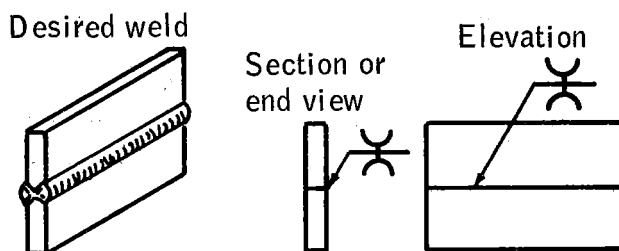
a. Arrow-side U-groove welding symbol



b. Other-side U-groove welding symbol



c. Both-sides U-groove welding symbol

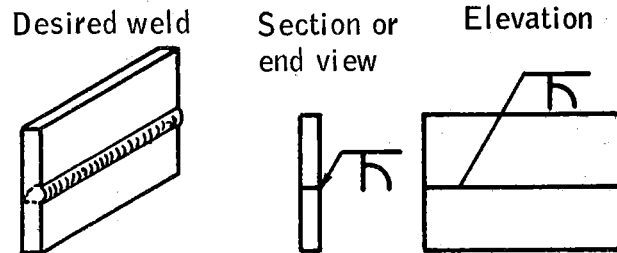




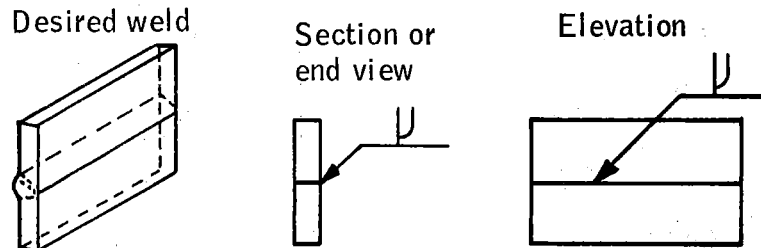
WELDING, BRAZING AND SOLDERING

21.3.12.4 Application of J-Groove Welding symbol

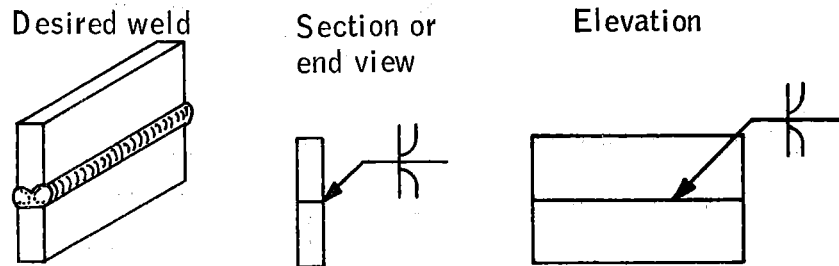
a. Arrow-side J-groove welding symbol



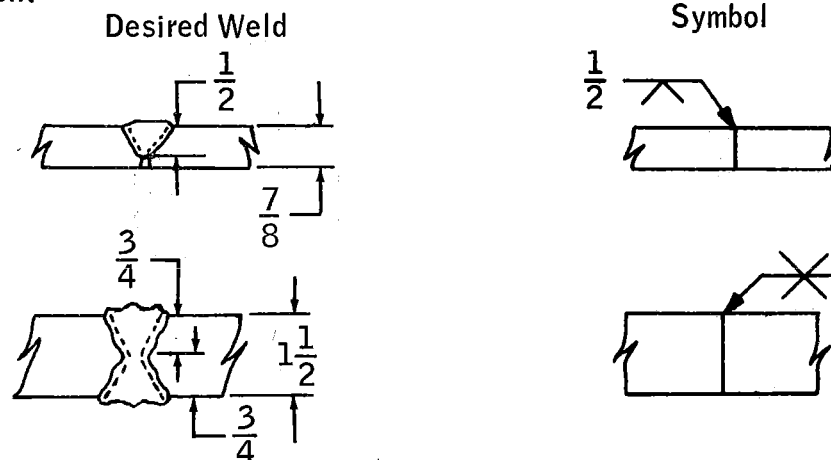
b. Other-side J-groove welding symbol



c. Both-sides J-groove welding symbol

21.3.12.5 Size of Groove Weld

Size of groove weld shall be shown to the left of the weld symbol unless defined in a note or specification.



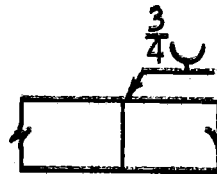
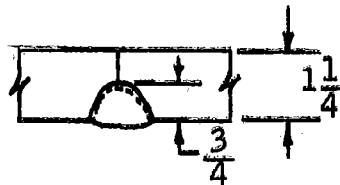
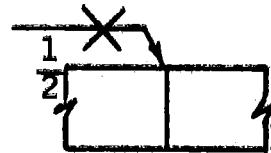
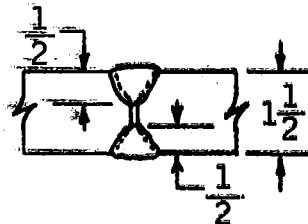
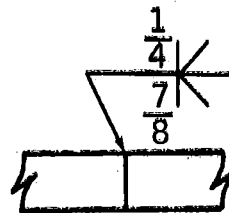
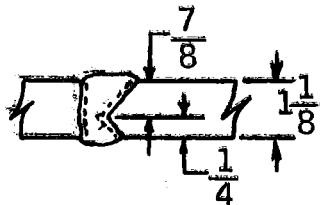
WELDING, BRAZING AND SOLDERING

21.3.12.5 (Contd)

Desired weld



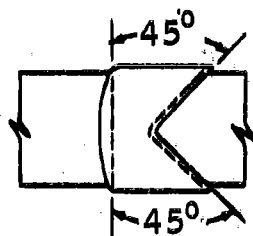
Symbol

21.3.12.6 Groove Angles, Root Openings, and Root Penetration

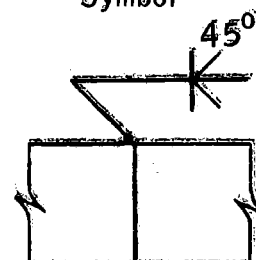
Groove angles, root openings, and root penetration (sometimes carried in the specifications) may be designated, when required.

a. Designation of groove angle of groove welds

Desired weld



Symbol





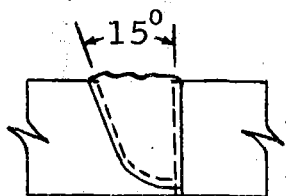
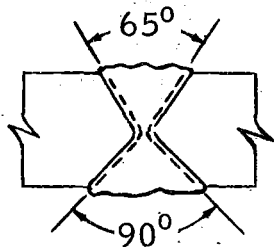
DATE 15 Sept. 1965

Ground Support Equipment

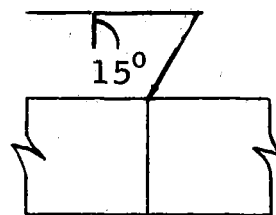
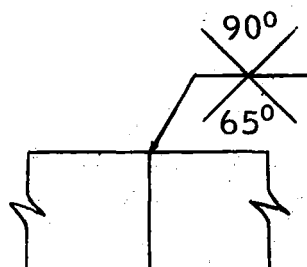
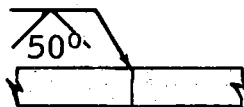
WELDING, BRAZING AND SOLDERING

21.3.12.6 (Contd)

Desired weld

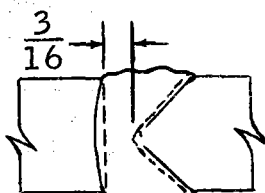
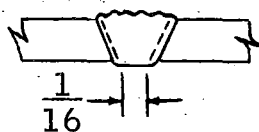


Symbol

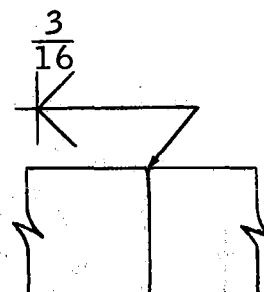
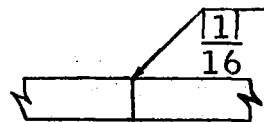


b. Designation of root opening of groove welds

Desired weld



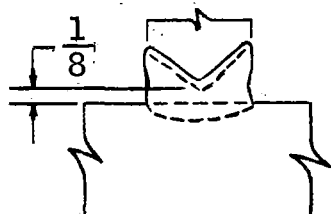
Symbol



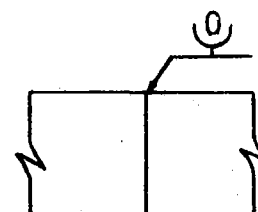
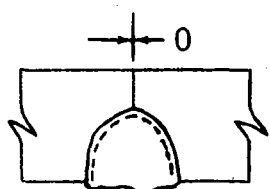
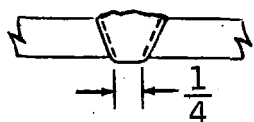
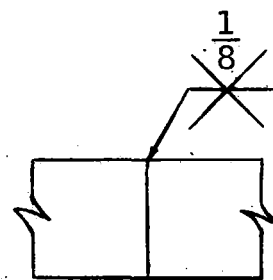
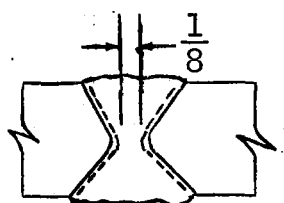
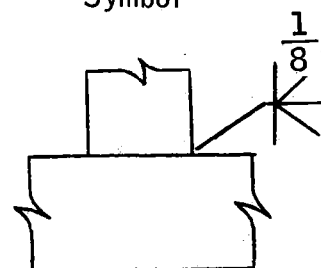
WELDING, BRAZING AND SOLDERING

21.3.12.6 (Contd)

Desired weld

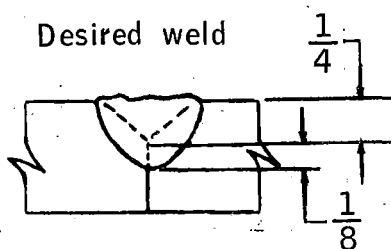


Symbol

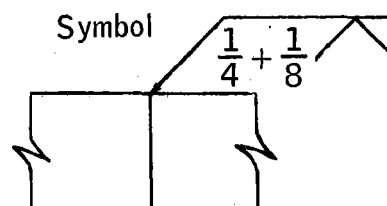


c. Designation of size of groove welds with specified root penetration

Desired weld



Symbol



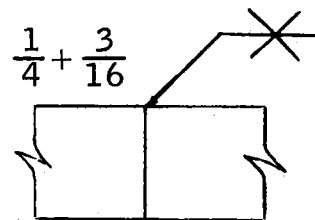
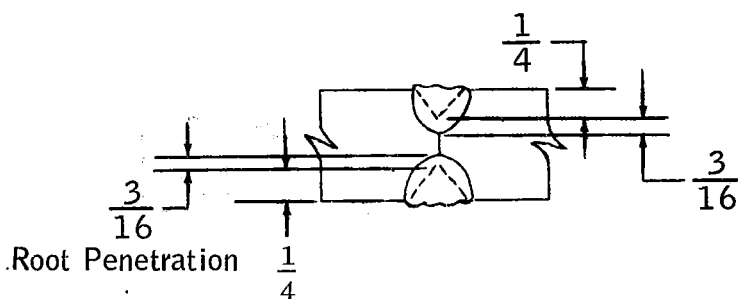


WELDING, BRAZING AND SOLDERING

21.3.12.6 (Contd)

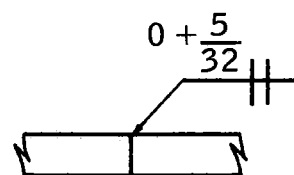
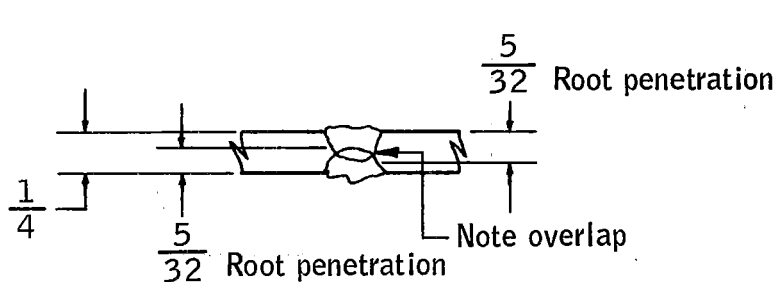
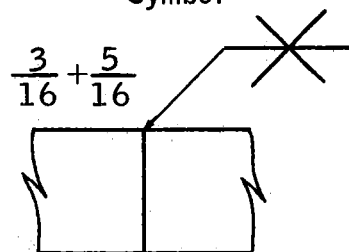
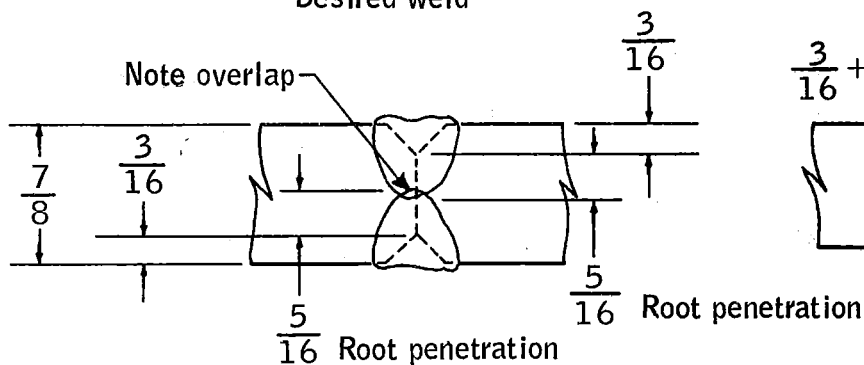
Desired weld

Symbol



Desired weld

Symbol



21.3.13 SURFACE WELDS

The surfacing weld symbol shall be used to indicate surfaces built up by welding.

21.3.13.1 Use of Surface Weld Symbol to Indicate Surfaces Built-up By Welding

- a. Surfaces built up by welding, whether by single or multiple-pass surfacing welds, shall be shown by the surfacing weld symbol, thus:



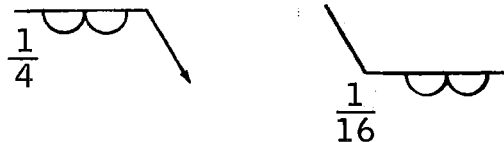
WELDING, BRAZING AND SOLDERING

21.3.13.1 (Contd)

- b. The surfacing weld symbol does not indicate the welding of a joint, and hence has no arrow- or other-side significance. This symbol shall be drawn on the side of the reference line toward the reader and the arrow shall point clearly to the surface on which the weld is to be deposited.
- c. Dimensions used in conjunction with the surfacing weld symbol shall be shown on the same side of the reference line as the weld symbol, thus:

21.3.13.2 Size (Height) of Surfaces Built Up by Welding

- a. The size of a surface built up by welding shall be indicated by showing the minimum height of the weld deposit to the left of the weld symbol, thus:



- b. When no specific height of weld deposit is desired, no size dimension need be shown on the welding symbol.

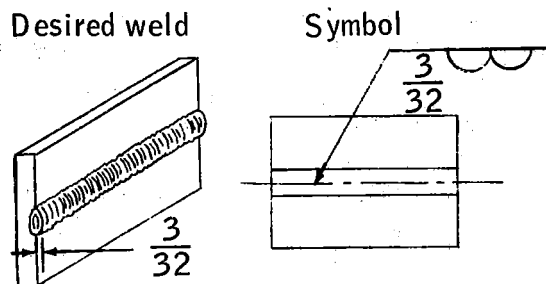
21.3.13.3 Extent, Location and Orientation of Surfaces Built Up by Welding

- a. When the entire area of a plane or curved surface is to be built up by welding, no dimension other than size (height of deposit) need be shown on the welding symbol.
- b. When a portion of the area of a plane or curved surface is to be built up by welding, the extent, location and orientation of the area to be built up shall be indicated on the drawing.

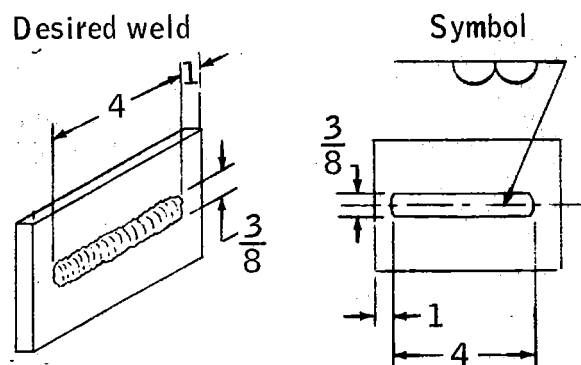
WELDING, BRAZING AND SOLDERING

21.3.13.4 Application of Surface Weld Symbol to Indicate Surfaces Built Up by Welding

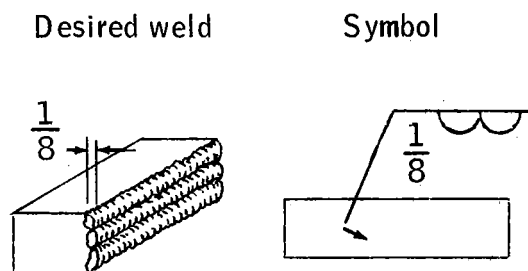
a. Size of surface built up by welding



b. Width and length of surface built up by welding



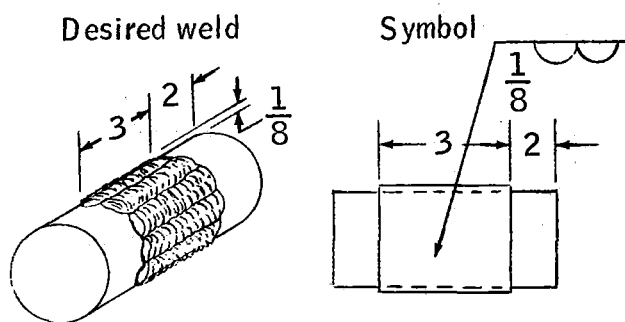
c. Entire surface built up by welding



WELDING, BRAZING AND SOLDERING

21.3.13.4 (Contd)

- d. Portion of surface built up by welding



21.3.14 FLANGE WELDS

The following welding symbols are intended to be used for light gage metal joints involving the flaring or flanging of the edges to be joined:

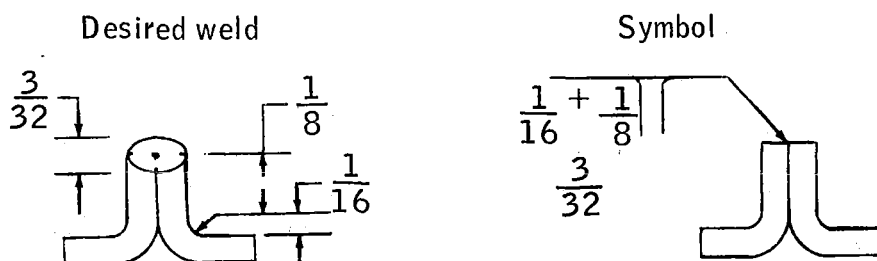
- a. Edge-flange welds shall be shown by the edge-flange weld symbol, thus: (this symbol has no both-sides significance)



- b. Corner-flange welds shall be shown by the corner-flange weld symbol, thus: (this symbol has no both-sides significance)

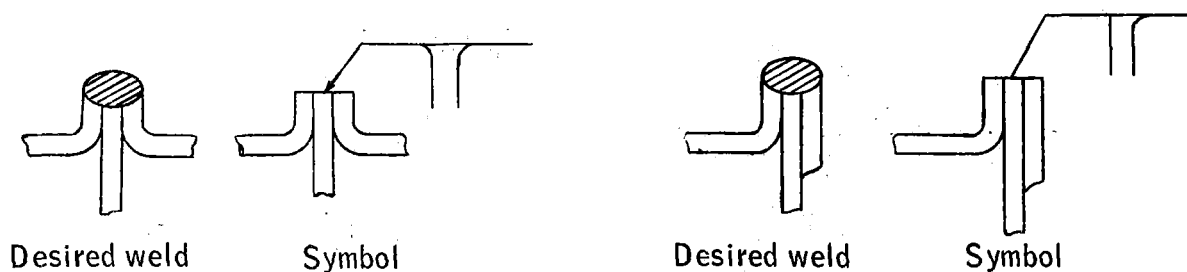


21.3.14.1 Application of Edge - and Corner-Flange Welding Symbols





21.3.14.1 (Contd)

21.3.14.2 Multiple Joint Flange Welds

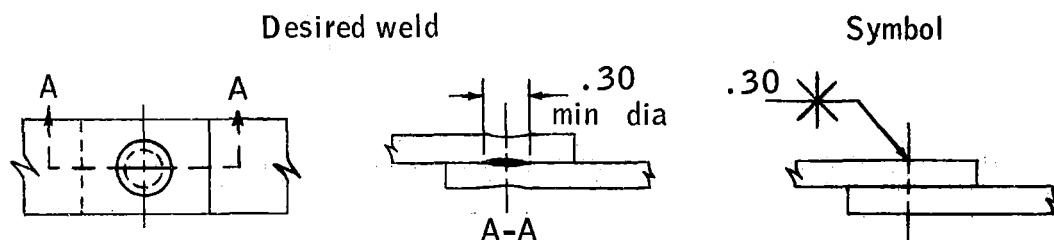
For flange welds, when one or more pieces are inserted between the two outer pieces, the same symbol as for the two outer pieces shall be used regardless of the number of pieces inserted.

21.3.15 RESISTANCE-SPOT WELDS

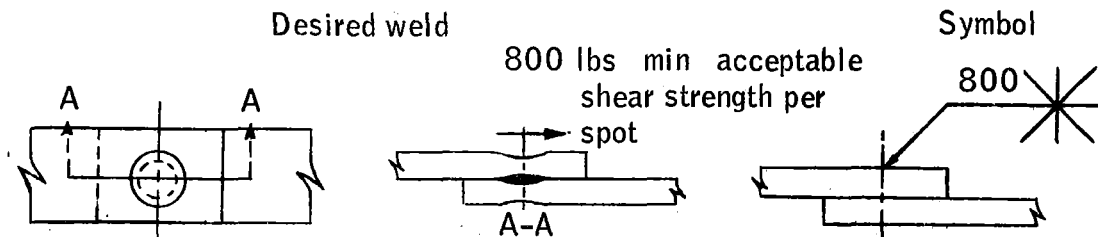
Resistance-spot weld symbols have no arrow- or other-side significance in themselves, although supplementary symbols used in conjunction therewith may have such significance. Resistance-spot weld symbols shall be centered on the referenced line.

21.3.15.1 Application of Dimensions to Resistance-Spot Welding Symbols

a. Diameter of resistance-spot welds



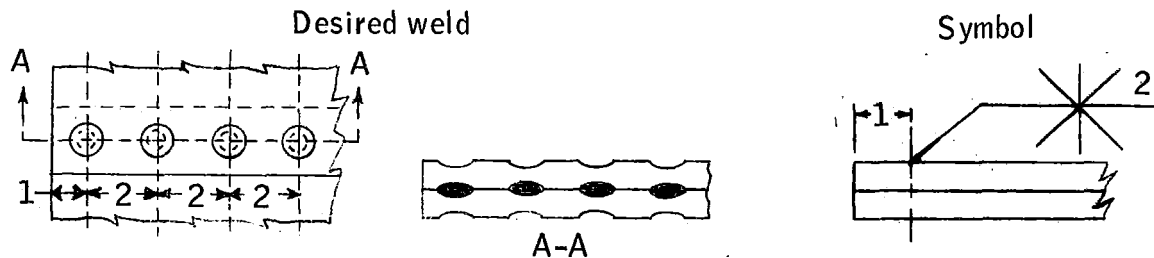
b. Shear strength of resistance-spot welds



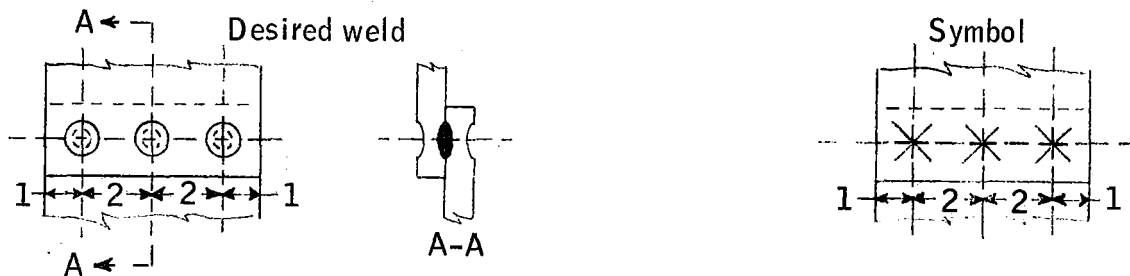
WELDING, BRAZING AND SOLDERING

21.3.15.1 (Contd)

c. Pitch of resistance-spot welds shown on symbol



d. Pitch of resistance-spot welds with symbol on drawing

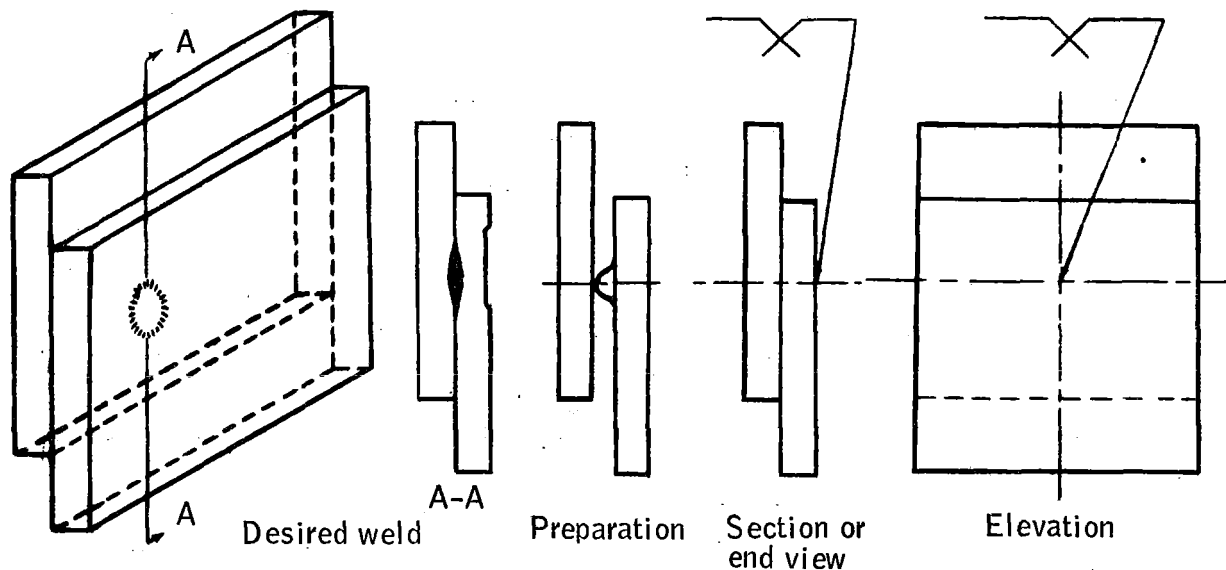


21.3.16 PROJECTION WELDS

- a. Embossments on the arrow-side member of a joint for projection welding shall be indicated by placing the weld symbol on the side of the reference line toward the reader.

21.3.16.1 Application of Projection Welding Symbol

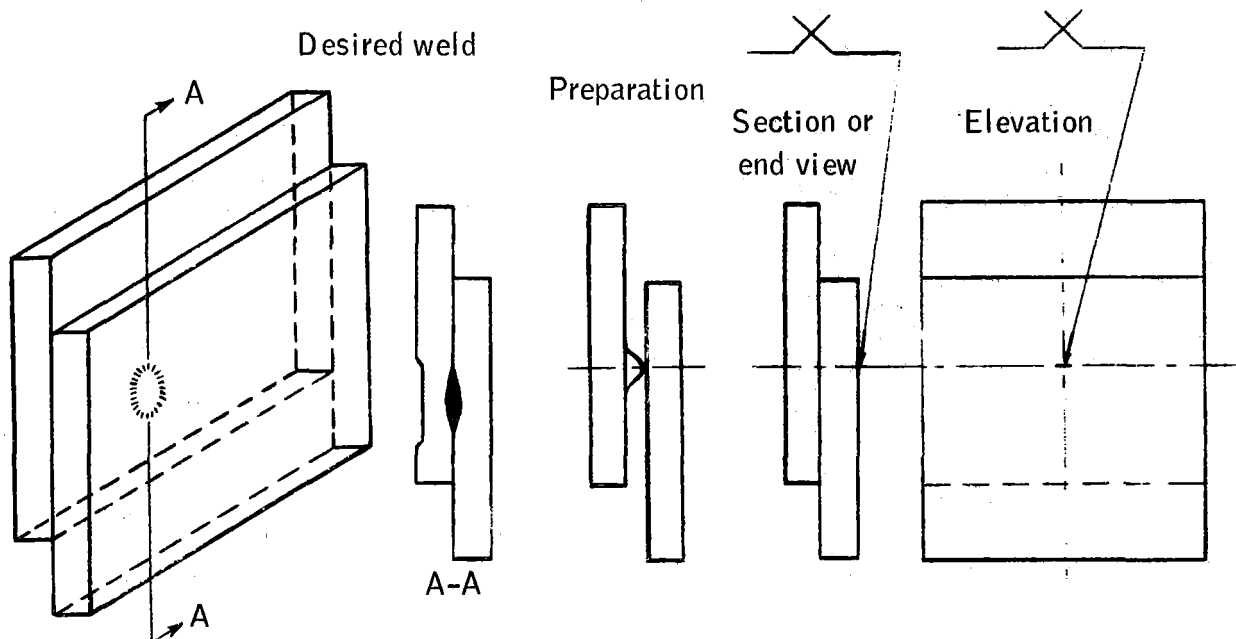
a. Arrow-side projection welding symbol



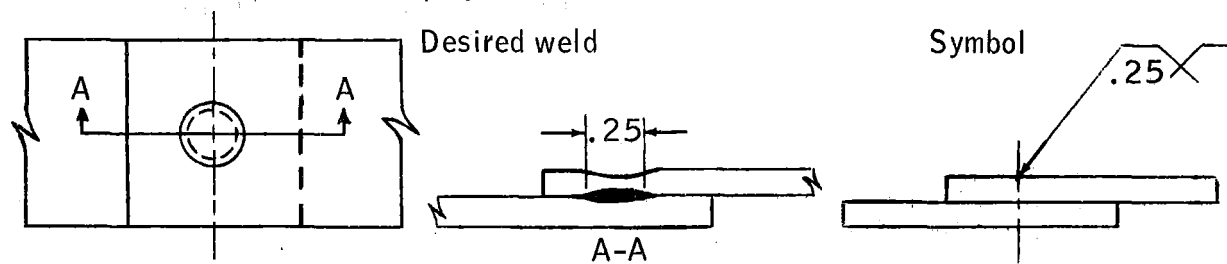
WELDING, BRAZING AND SOLDERING

21.3.16.1 (Contd)

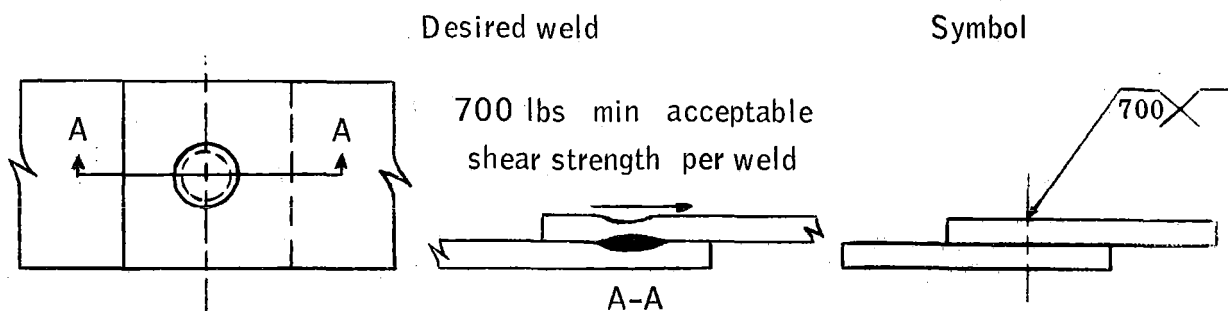
b. Other-side projection welding symbol

21.3.16.2 Application of Dimensions to Projection Welding Symbol

a. Diameter of projection welds

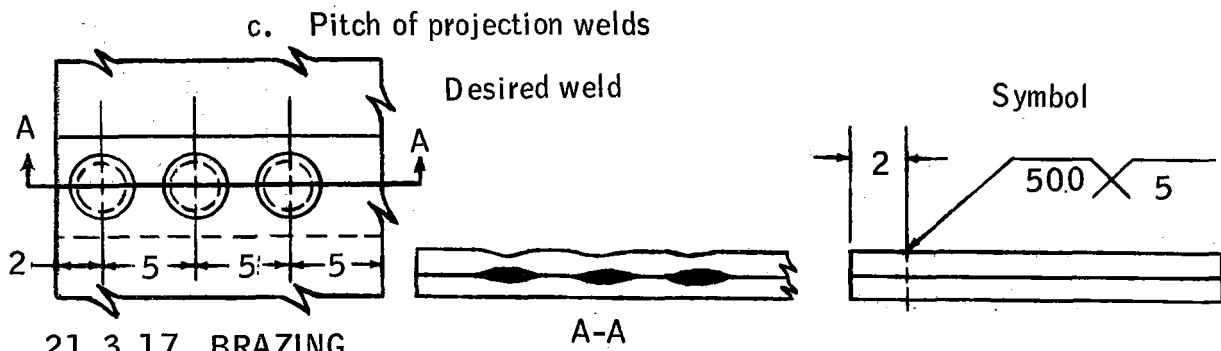


b. Shear strength of projection welds

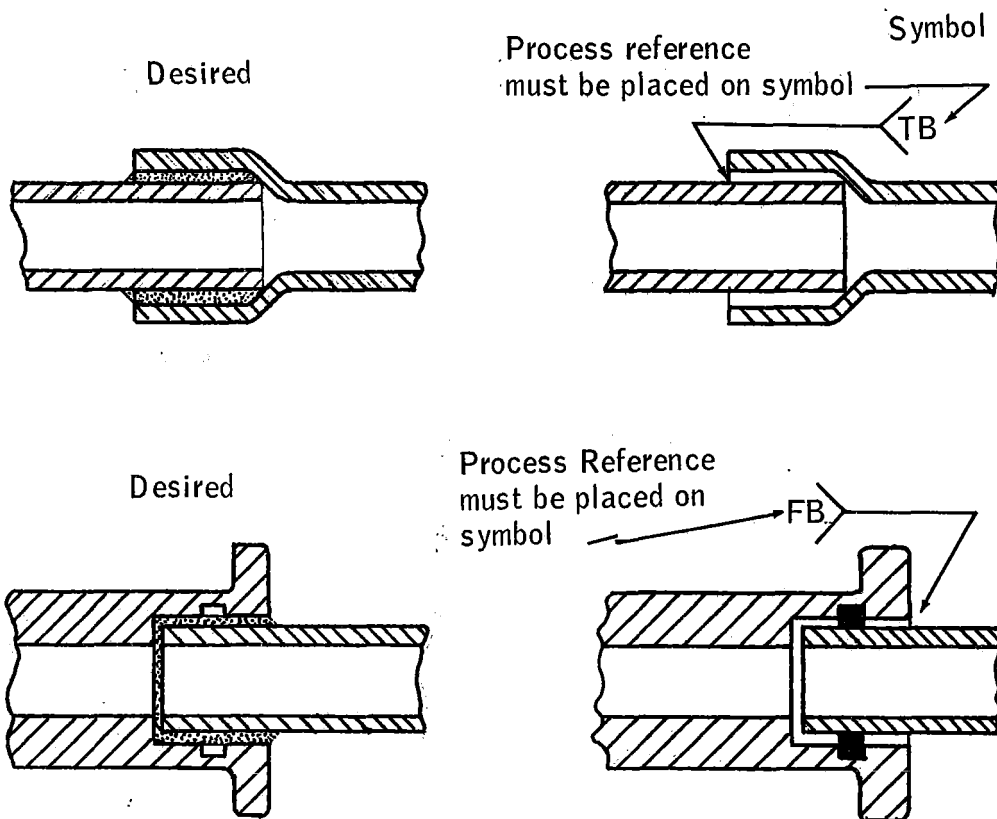


WELDING, BRAZING AND SOLDERING

21.3.16.2 (Contd)



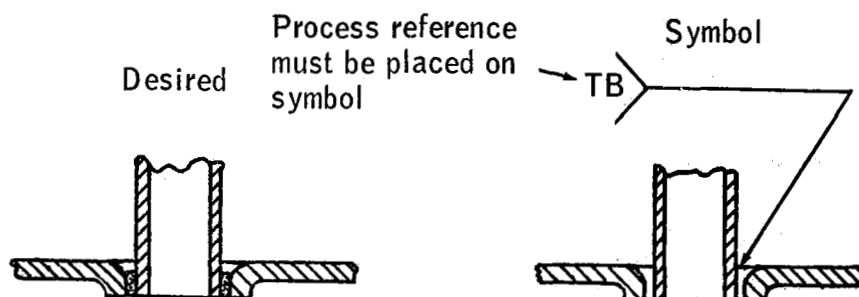
Brazing shall be indicated by using a process or specification reference in the Tail of the Welding symbol.





WELDING, BRAZING AND SOLDERING

21.3.17 (Contd)

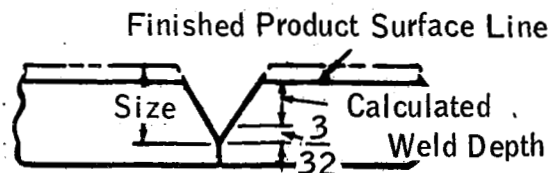
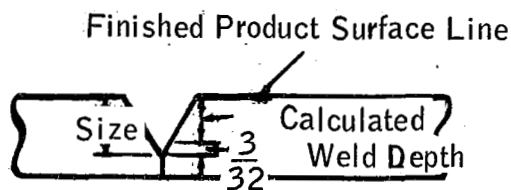
21.4 DESIGN DATA

21.4.1 GROOVE WELDS

The size of a groove weld is the depth of the groove. (Weld depth of all groove welds assumed to be equal to plate thickness unless otherwise specified.)

When weld depth equals plate thickness, (1), a backing strip may be used (when all welding must be done from one side), or (2), the back side of the weld may be chipped to sound metal and welded. (When no backing strip is used, provision must be made for welding from both sides.)

In a "V" groove, when the required weld depth is less than plate thickness, the groove should be made $3/32$ inches deeper than the calculated weld depth to allow for incomplete penetration.



It is standard shop practice to reinforce all groove welds (except flush groove welds) a definite standard amount.

Minimum Reinforcement

Single-pass welds	-	$1/16$ inches
Multi-pass welds	-	$1/8$ inches

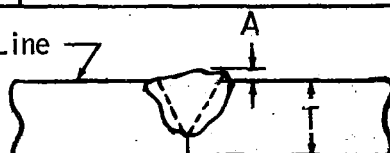
WELDING, BRAZING AND SOLDERING

21.4.1 (Contd)

It is possible to make welds flush with the base material within the following tolerances without a finish operation.

T = Plate thickness, inches	A = Tolerance, inches
Up to 1/4 excl	-0 to +1/16
1/4 and over	-0 to +3/32

Finished Product Surface Line

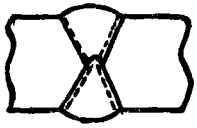
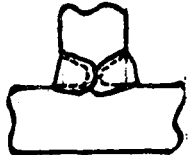




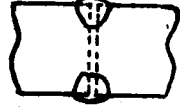



21.4.2 SELECTION OF GROOVE

The groove preparation shall not only be accessible, but it shall be of such nature that the side walls are visible to the operator while he is making the weld.

Standard groove preparation shall be used whenever feasible. The following page gives information to aid in the proper use of standard grooves. The "U", Modified "U", and "J" grooves are recommended for use in the flat position only. When positioning of the work is not practical, it is recommended that the "V" or Double "V" groove be used.



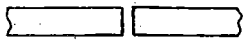
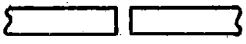






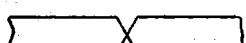
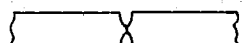




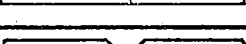






21.4.2.1 Cost

High Cost	Intermediate Cost		Low Cost
 	 	 	 



WELDING, BRAZING AND SOLDERING

21.4.2.2 Selection of Groove for Butt Joint

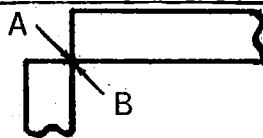
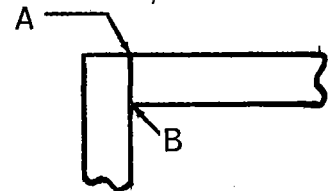
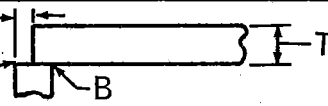
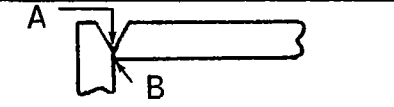
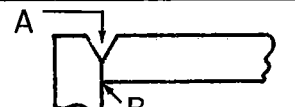
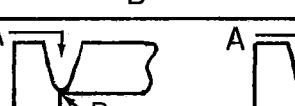
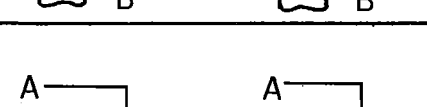
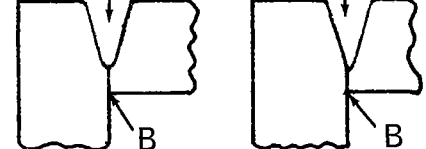
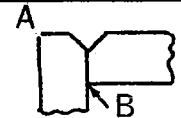
Plate Thickness (in)	Type of Groove	Weld Depth	One Side	Both Sides (See note)
1/8 to 1/4 inch	Square	Plate Thickness	 *	
1/8 to 3/8 inch	Square	Less than Plate Thickness		
1/4 to 1 1/4	V	Plate Thickness	 *	
		Less than Plate Thickness		
1 1/4 to 2 1/2	V U, or Mod U	Plate Thickness	 *  *	 
		Less than Plate Thickness but 1 1/4" or greater	 	 
		Less than 1 1/4"		
2 1/2 up	U Mod U or V	Plate Thickness	See Above (U or Mod U)	 
		Less than Plate Thickness but 2 1/2" or greater	See Above (U or Mod U)	 
		Less than 2 1/2"	See Above (U or Mod U) (V for Depth less than 1-1/4")	

*With or without permanent backing strip.

Note: "Both sides" preferred to "One side", accessibility and shop facilities permitting.

WELDING, BRAZING AND SOLDERING

21.4.2.3 Selection of Groove for L-Joint

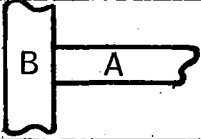
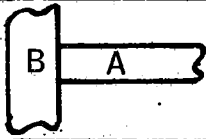
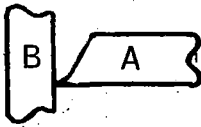
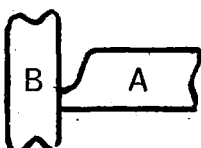
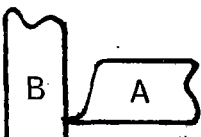
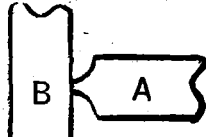
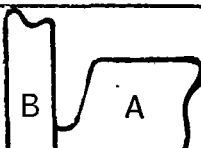
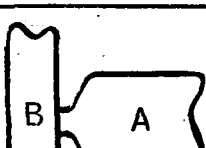
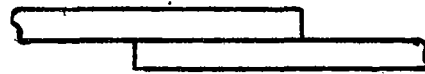
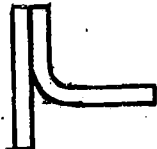
Plate Thickness (in.)	Type of Weld	Weld Depth	Joint Cross Section
All	Fillet at "A" *		
All	Fillet at "B"		
All	Square Groove at "A" *	Partial Penetration	
1/8 to 3/8	Fillet at "A" *	Partial Penetration	
1/4 to 1 1/4	V Groove at "A" *	Plate Thickness	
		Less Than Plate Thickness	
1 1/4 Up	U or Mod U Groove *	Plate Thickness	
		Less Than Plate Thickness but 1 1/4" or Greater	
	V Groove *	Less Than 1 1/4"	

*With or without a fillet weld at "B".

Note: A small weld at "A" and "B" is better than a large weld at "A" or "B". Where possible, extend one member to form a T-joint and use fillet welds.

WELDING, BRAZING AND SOLDERING

21.4.2.4 Selection of Groove for T, Lap and Edge Joints

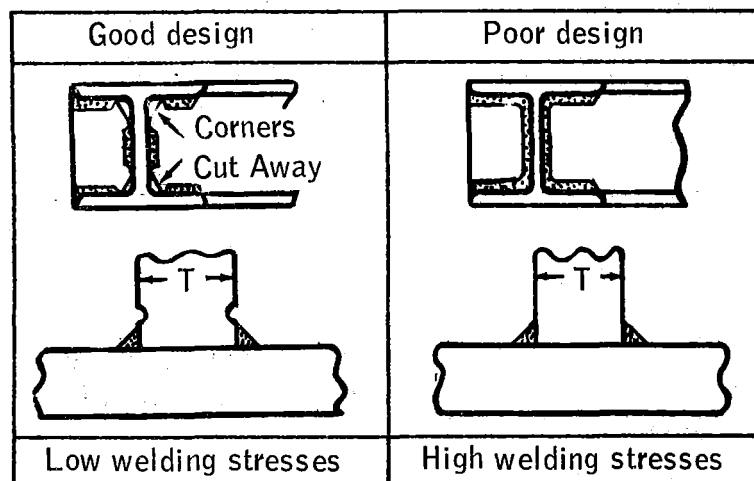
Joint	Plate Thickness		Type of Weld	Weld Depth	One Side	Both Sides (See note)
	A	B				
T*	All	All	Fillet	— —		
	1/2" to 1"	All	J Groove	Plate Thickness		— —
				Less than Plate Thickness but 3/8" or Greater		— —
	1" up	All	J Groove	Plate Thickness		
				Less than Plate Thickness but 3/8" or Greater		
	Lap	All	Fillet	— —		
Edge	1/16" to 3/16"		Square Groove	Partial Penetration		
<p>*With or without a fillet weld on either or both sides of the above T-joints.</p> <p>Note: A small weld on both sides is better than a large weld on either side.</p>						

WELDING, BRAZING AND SOLDERING

21.4.2.5 Accessibility

Parts and welds must be arranged so that welds are accessible for welding, testing, and repairing with a minimum of handling.

21.4.3 RIGIDITY AND THICKNESS

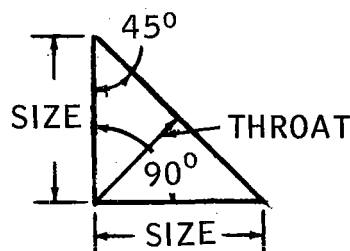


T-2 inches or more

21.4.4 CODE REQUIREMENTS

If the requirements of a specified code must be met, refer to the code in selecting the joint design and class of weld.

21.4.5 FILLET WELDS

21.4.5.1 Standard Fillet Cross Section



WELDING, BRAZING AND SOLDERING

21.4.5.1 (Contd)

■ The minimum size of fillet weld recommended for a given plate thickness is as follows:

Thickness of thinnest plate, inch	Minimum fillet size, inch
1/8 to 5/16	3/16
5/16 to 7/8	1/4
7/8 up	5/16

21.4.5.2 Fillet Welding - General

The size of a fillet weld other than standard shall be determined by the length of the leg of the largest 45° right triangle (standard fillet) that can be inscribed within the contour of the cross section of the weld.

The minimum length of an intermittent fillet weld shall be at least 4 times the size of the weld and in no case less than one inch.

Intermittent fillet welds should be opposite each other. Staggered welds are not recommended.

Intermittent fillet welds larger than 3/8 inches are not recommended.

■ Metal to metal contact of joining members shall be maintained wherever possible. Maximum gap 3/32 inches may be permitted for processing reasons.

21.4.6 WELDING OF STORAGE AND UNFIRED PRESSURE VESSELS

The welding of storage and pressure vessels shall be in accordance with the designated code or specification.

Since the requirements for this type of welding are more stringent than structural welding, the designer shall be familiar with the code or specification, or secure weld design approval from the responsible engineering activity.

WELDING, BRAZING AND SOLDERING

21.4.7 ALUMINUM ALLOYS

21.4.7.1 Base Metals and Compatible Filler Metals ¹

BASE METAL	43, 355, 356	214, A214, B214, F214	6061, 6062, 6063, 6151	5456	5454	5154, 5254	5086, 5356	5083	5052, 5052	5005, 5050	3004 CLAD 3004	1100, 3003 CLAD 3003	1060
1060	ER4043	ER4043	ER4043	ER5356	ER4043	ER4043	ER5356	ER5356	ER4043	ER1100	ER4043	ER1100	ER1260
1100, 3003 CLAD 3003	ER4043	ER4043	ER4043	ER5356	ER4043	ER4043	ER5356 ER5356	ER5356 ER5356	ER4043 ER5356	ER4043 ER4043	ER4043 ER4043	ER1100	
3004, CLAD 3004	ER4043	ER4043	ER4043	ER5356	ER5356	ER5356	ER5356 ER5356	ER5356 ER5356	ER4043 ER5356	ER4043			
5005, 5050	ER4043	ER4043	ER4043	ER5356	ER4043	ER5356	ER5356	ER5356	ER5183				
5052, 5052	ER4043	ER4043	ER4043	ER5356	ER5356	ER5356	ER5356						
5083	ER5356	ER5356	ER5356	ER5183	ER5356	ER5356							
5086, 5356	ER5356	ER5356	ER5356	ER5356	ER5356	ER5356							
5154, 5254	ER5356	ER5356	ER5356	ER5356	ER5356	ER5356	ER5254						
5454	ER5356	ER5356	ER5356	ER5356	ER5356								
5456	ER5356	ER5356	ER5356	ER5356									
5061, 6062, 6063, 6151	ER4043	ER5356	ER5356										
214, A214, B214, F214	ER4043	ER5356											
43, 355, 356	ER4043												

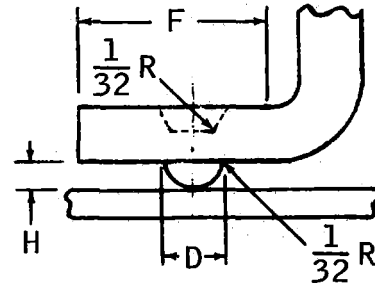
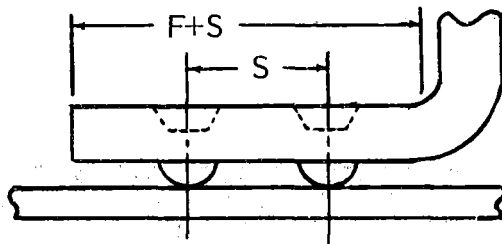
¹ Designation numbers are from the AWS-ASTH Specification for Aluminum and Aluminum Alloy Welding Rods and Bare Electrodes (AWS 5.10; ASTH B285).



WELDING, BRAZING AND SOLDERING

21.4.8 RESISTANCE WELDING

21.4.8.1 Projection Welds







Thickness, inch		Projection size (1)		Min spacing S, in.	Min flange F, in.	Weld dia in.	Sheet separation in. (2)
From	To & excl	Height, H, inch	Diameter, D, inch				
.010	.016	.016 $\begin{smallmatrix} +.001 \\ -.002 \end{smallmatrix}$.057 $\begin{smallmatrix} +.003 \\ -.001 \end{smallmatrix}$	3/16	5/32	1/16	.003
.016	.025	.019 $\begin{smallmatrix} +.001 \\ -.002 \end{smallmatrix}$.070 $\begin{smallmatrix} +.003 \\ -.001 \end{smallmatrix}$	7/32	3/16	3/32	.003
.025	.034	.024 $\begin{smallmatrix} +.001 \\ -.002 \end{smallmatrix}$.094 $\begin{smallmatrix} +.003 \\ -.001 \end{smallmatrix}$	9/32	1/4	1/8	.005
.034	.050	.031 $\begin{smallmatrix} +.002 \\ -.003 \end{smallmatrix}$.125 $\begin{smallmatrix} +.005 \\ -.002 \end{smallmatrix}$	3/8	5/16	5/32	.005
.050	.062	.037 $\begin{smallmatrix} +.002 \\ -.003 \end{smallmatrix}$.156 $\begin{smallmatrix} +.005 \\ -.002 \end{smallmatrix}$	15/32	3/8	7/32	.010
.062	.085	.043 $\begin{smallmatrix} +.002 \\ -.003 \end{smallmatrix}$.188 $\begin{smallmatrix} +.005 \\ -.002 \end{smallmatrix}$	9/16	7/16	9/32	.010
.085	.109	.056 $\begin{smallmatrix} +.002 \\ -.003 \end{smallmatrix}$.250 $\begin{smallmatrix} +.005 \\ -.002 \end{smallmatrix}$	3/4	1/2	5/16	.010
.109	.140	.062 $\begin{smallmatrix} +.003 \\ -.004 \end{smallmatrix}$.281 $\begin{smallmatrix} +.007 \\ -.003 \end{smallmatrix}$	27/32	5/8	7/16	.010
.140	.170	.068 $\begin{smallmatrix} +.003 \\ -.004 \end{smallmatrix}$.312 $\begin{smallmatrix} +.007 \\ -.003 \end{smallmatrix}$	15/16	3/4	1/2	.010
.170	.203	.081 $\begin{smallmatrix} +.003 \\ -.004 \end{smallmatrix}$.375 $\begin{smallmatrix} +.007 \\ -.003 \end{smallmatrix}$	1-1/8	7/8	9/16	.015
.203	.250	.093 $\begin{smallmatrix} +.003 \\ -.004 \end{smallmatrix}$.438 $\begin{smallmatrix} +.007 \\ -.003 \end{smallmatrix}$	15/16	1-1/8	11/16	.015

- (1) The size of the projection is normally determined by the thickness of the thinner sheet.
- (2) Sheet separation is the distance between sheets after the weld is completed.

WELDING, BRAZING AND SOLDERING

General Rules - Projection Welding

1. Weld must start with a point contact and have a continuously increasing cross section to the finish of the weld.
2. Projection should be made on thicker piece.
3. Projection height should be between 10 and 75 percent of material thickness.
4. Studs, either plain or threaded, should be domed and may or may not be headed.

GOOD DESIGN	POOR DESIGN
 <p>Avoids shearing</p>	 <p>Plug may become loose or burn off on a line with the upper surface of the sheet.</p>
 <p>Maintains symmetry, therefore projection will push down straight without spreading</p>	 <p>Incorrect projection</p>

Size of Projection

Depends upon

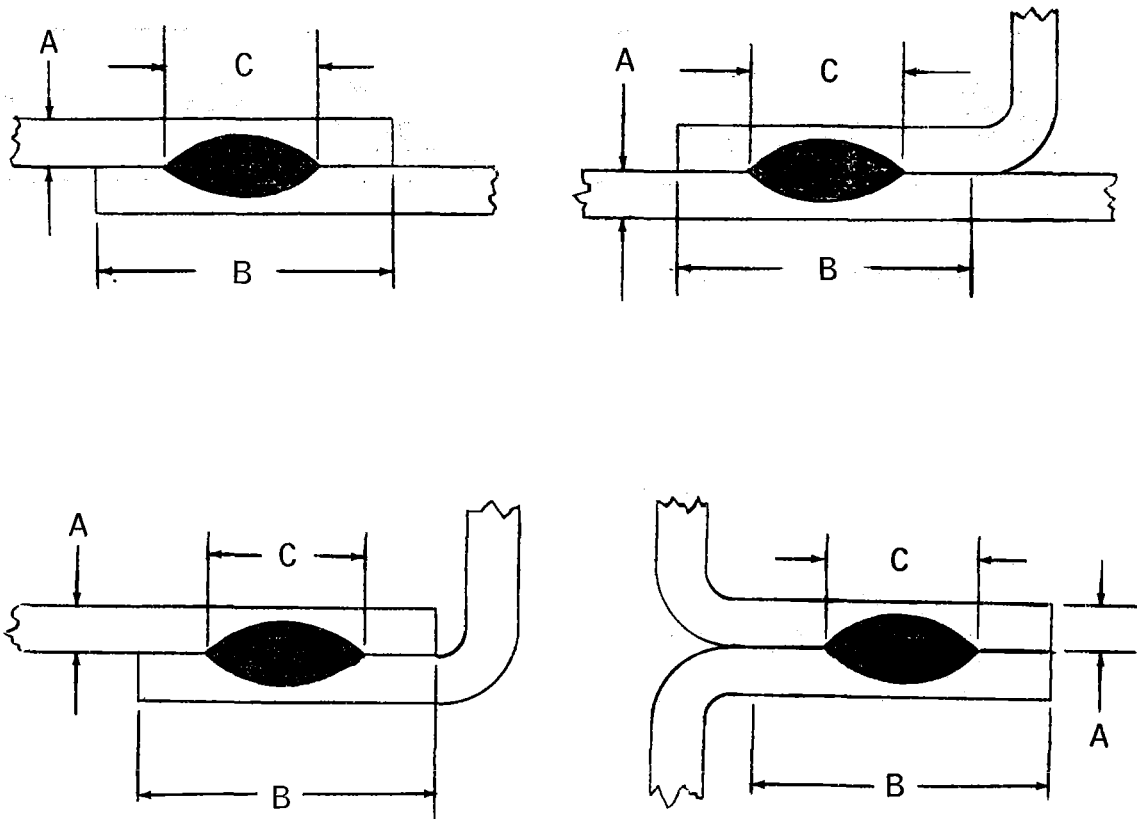
1. Strength requirements
2. Number of projections used
3. Material
4. Degree of freedom from marking
5. Space available for welding



WELDING, BRAZING AND SOLDERING

21.4.8.2 Spot Welds

1. Material must be clean and free from oil, dirt, scale and oxides.
2. The flanges and overlaps, dimension B below, must be flat.
3. Minimum weld spacing listed below applies only in those instances where it is not necessary to compensate for shunted current effect of adjacent welds when using two thicknesses of material.
4. Minimum edge distance (from center of weld to the edge of the material) is half the length shown for minimum contacting overlap.
5. Limit total thickness of pile-up to four times the thickness of the thinnest outside piece.





WELDING, BRAZING AND SOLDERING

21.4.8.3 Design Data for Spot Welding Low Carbon Steel

The thickness ratio of the thicker piece to the thinner piece should not exceed 3 to 1.

Thickness of thinner sheet inch, A	Diameter of weld, inch, C	Minimum contacting overlap in., B	Minimum weld spacing centerline to centerline, in.
.031	3/16	7/16	1/2
.040	7/32	1/2	3/4
.050	1/4	9/16	7/8
.078	9/32	11/16	1-1/4
.109	11/32	13/16	1-1/2
.125	3/8	7/8	1-3/4

21.4.8.4 Design Data for Spot Welding Aluminum

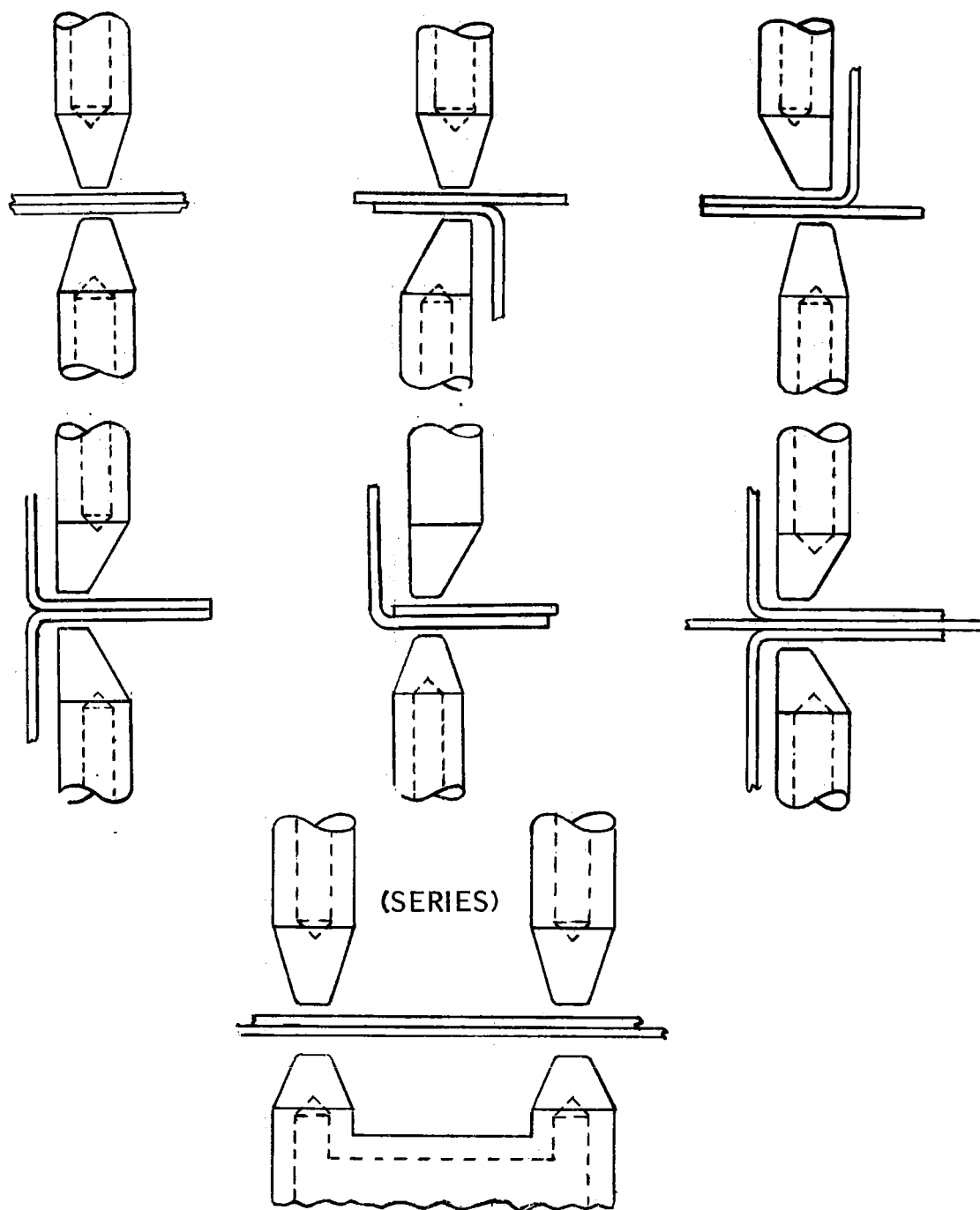
The thickness ratio of the thicker piece to the thinner piece should not exceed 4 to 1.

Thickness combination inches	Diameter of weld, in., C	Minimum contacting overlap in., B	Minimum weld spacing, centerline to centerline, inch
.032 to .032	3/16	1/2	3/4
	.064 3/16	1/2	3/4
	.091 3/16	5/8	1
	.125 3/16	5/8	1
.064 to .032	1/4	1/2	3/4
	.064 1/4	5/8	1
	.091 1/4	3/4	1
	.125 1/4	3/4	1
.091 to .032	5/16	5/8	1
	.064 5/16	3/4	1
	.091 5/16	1	1
	.125 5/16	1	1
.125 to .032	3/8	5/8	1
	.064 3/8	5/8	1
	.091 3/8	1	1
	.125 3/8	1 1/4	1 1/2

WELDING, BRAZING AND SOLDERING

21.4.8.5 Standard Welding Equipment

Designs should accommodate the following normal positions of standard welding points or wheels wherever possible:



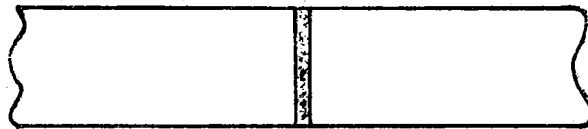
WELDING, BRAZING AND SOLDERING

21.4.9 BRAZING

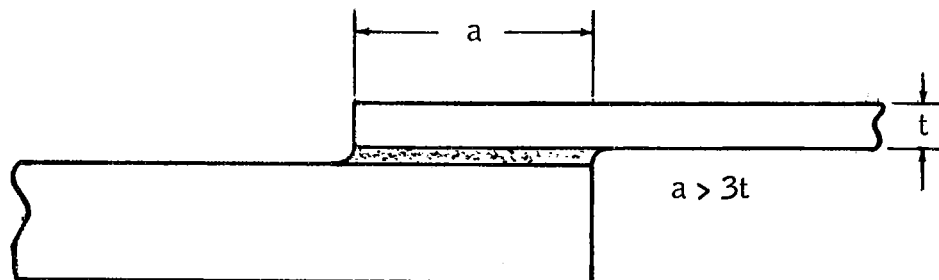
The brazing process is used when a ductile joint is desired that will have high strength and resistance to fatigue and corrosion at a reasonable cost. It is also a useful means of joining dissimilar metals. Brazed joints are able to withstand higher service temperatures and higher service stresses than ones which are soldered.

21.4.9.1 Types of Joints

- a. Butt Joint - The butt joint is weaker and has higher electrical resistance than the other joints listed below and is limited to use when service requirements are not severe and leak tightness and strength are relatively unimportant. It is also difficult to support and position during brazing.



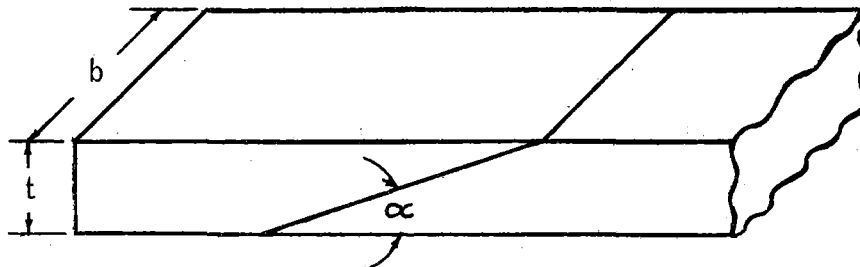
- b. Lap Joint - The lap joint and variations thereof should be employed whenever possible. The lengths of overlap, "a", may be adjusted to make the joint as strong as the weakest member despite the lower unit strength of the filler metal or the presence of small defects in the braze. An overlap, "a", greater than three times the thickness of the thinnest member, "t", will usually yield 100% joint efficiency.



WELDING, BRAZING AND SOLDERING

21.4.9.1 (Contd)

- c. Scarf Joint - The use of a scarf joint is somewhat questionable unless brazed area is over three times the normal cross-section area. Scarf joints are more difficult to prepare and harder to hold in alignment during brazing than are lap or butt joints.

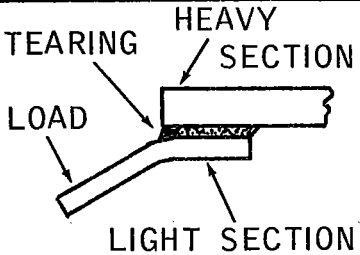
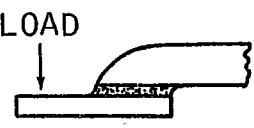

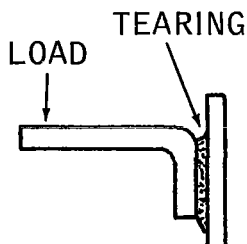
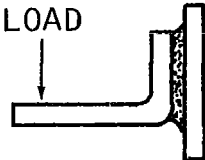
Angle α $19\ 1/2^{\circ}$ * 30° + 42° +

Brazed area	Cross-section area
	3
	2
	1.5

* Recommended maximum angle.

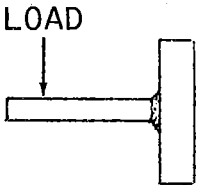
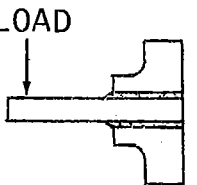
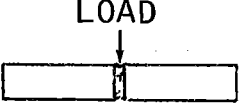
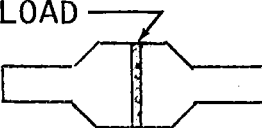
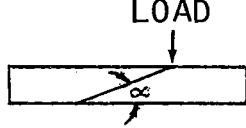
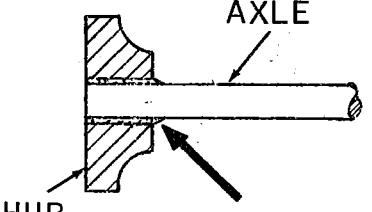
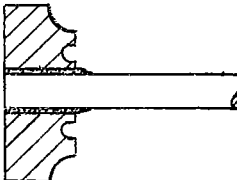
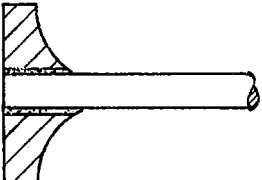
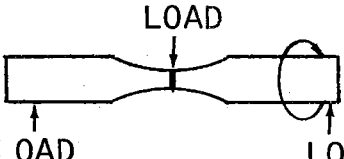
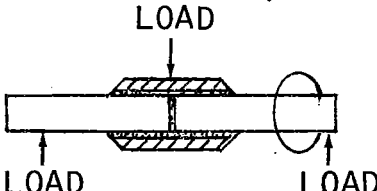
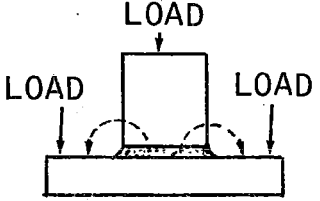
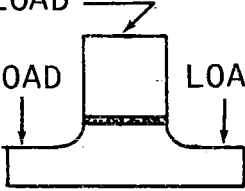
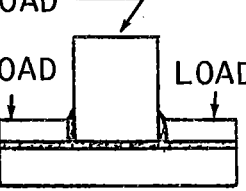
+ Not recommended (for information only).

21.4.9.2 Joint Design

POOR DESIGN	IMPROVED DESIGN	
 <p>TEARING LOAD HEAVY SECTION LIGHT SECTION</p>	 <p>LOAD</p> <p>Shape heavy section to reduce stress</p>	 <p>LOAD</p> <p>Increase thickness of light section at joint</p>
 <p>LOAD TEARING</p>	 <p>LOAD</p> <p>Improves resistance to impact and fatigue.</p>	

WELDING, BRAZING AND SOLDERING

21.4.9.2 (Contd)

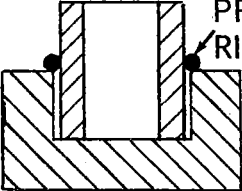
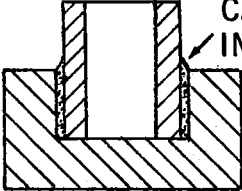
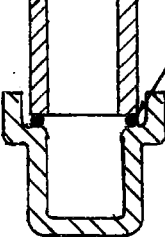
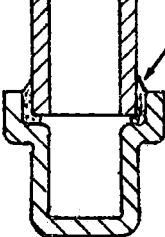
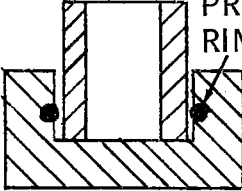
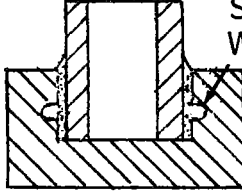
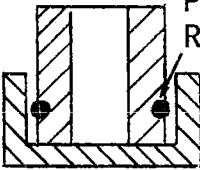
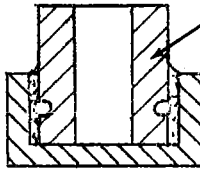
POOR DESIGN	IMPROVED DESIGN
	 <p>Improves resistance to impact and fatigue</p>
 <p>Poor impact strength caused by butt joint having the same cross sectional area as rest of joint assembly.</p>	<div style="display: flex; justify-content: space-around;"> <div>  <p>Increase thickness at joint.</p> </div> <div>  <p>Angle α should be low, preferably under 20°</p> </div> </div>
 <p>FATIGUE CAN START HERE BECAUSE OF AXLE FLEXING</p>	<div style="display: flex; justify-content: space-around;">   </div> <p>Flexible flange permits flexing of axle and hub as a unit.</p>
<p>Rotating beam—poor fatigue life.</p> 	<p>Sleeve increased fatigue life.</p> 
 <p>Couples at the joint should be avoided</p>	<div style="display: flex; justify-content: space-around;"> <div>  <p>Increase thickness at joint</p> </div> <div>  <p>A changed design is preferred.</p> </div> </div>



WELDING, BRAZING AND SOLDERING

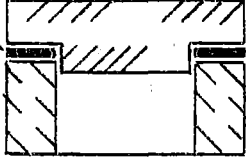
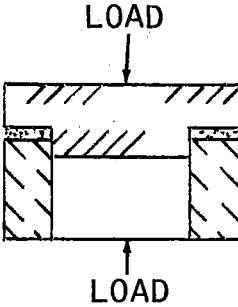
21.4.9.3 Design for Feeding Filler Metal Into Joint

Allowances must be made for the effective introduction of filler metal. If face fed by hand, the joint must be exposed. If preplaced in or adjacent to the joint, there are many methods depending on the design. The following illustrates a few typical designs:

BEFORE BRAZING	AFTER BRAZING
<p>Wherever possible the metal flow should be assisted by gravity and provision should be made for inspection of the joint to insure complete filling.</p>  <p>PREPLACED RING</p>	 <p>CAN BE INSPECTED</p>
 <p>PREPLACED RING</p>	 <p>CAN BE INSPECTED</p>
<p>The filler metal may be inserted in a groove providing that the heavier section is grooved. The filler metal leaves the groove to distribute itself throughout the joint. Therefore, it is necessary to subtract the grooved area from the joint area when designing for mechanical strength.</p>  <p>PREPLACED RING</p>	 <p>HEAVIER SECTION WAS GROOVED</p>
 <p>PREPLACED RING</p>	 <p>HEAVIER SECTION WAS GROOVED</p>

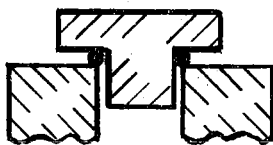
WELDING, BRAZING AND SOLDERING

21.4.9.3 (Contd)

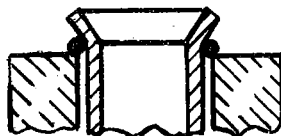
BEFORE BRAZING	AFTER BRAZING
<p>If flat washers or shims are used as preplacement forms, it is necessary to provide for application of pressure to the joint or other means of assuring proper flow of filler metal.</p> <p>PREPLACED WASHER</p> 	

21.4.9.4 Assembly of Joints

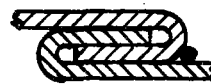
The simplest assembly method capable of securely holding the joint members in correct alignment and maintaining clearance during the heating and cooling cycle is always preferable. If possible the joint should be designed to be self-locating. Following are several typical designs:



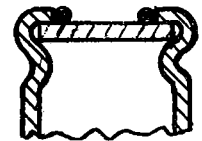
Held by gravity



Held by expanding tube and gravity



Held by interlocking seam



Held by crimping



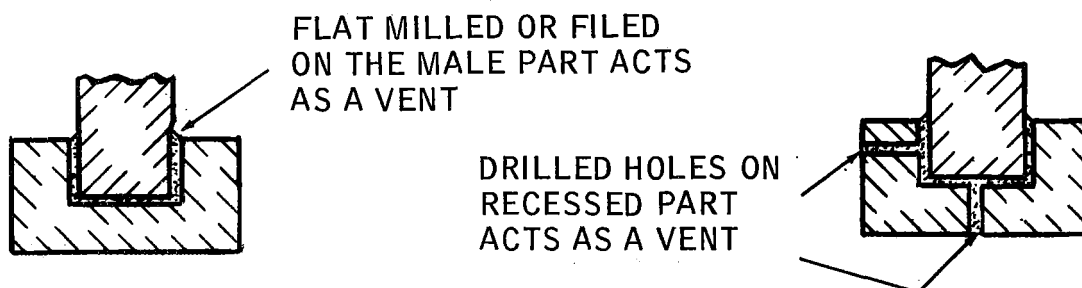
WELDING, BRAZING AND SOLDERING

Joints can also be held in alignment by arc tack welding prior to brazing. It is sometimes necessary to use jigs in the form of clamps and supports. While this is not a primary concern to the designer, he should be aware of the following problems that can be attributed to poor supports:

1. The mass of the support should be as small as possible in order that it will not interfere with the even heating of the pieces being brazed by removing heat. Also the support should not impede the flow of filler metal.
2. Expansion of the support during brazing should be such as to assure the maintenance of proper joint clearance.
3. At point of contact the support must not alloy or fuse to the base metal. Also the support should not be wet by the filler metal or else it is liable to become brazed to the assembly.

21.4.9.5 Pressure Tight Assemblies

A pressure or vacuum tight assembly must be joined by a lap joint with provision for proper venting of the heated gases formed during the brazing operation. Otherwise the expansion of hot gases can force the assembly apart or expel the molten filler metal from the joint. Dead end holes may be regarded as small pressure containers. Following are some typical ways to provide venting.



WELDING, BRAZING AND SOLDERING

21.4.9.6 Joint Clearances

The choice of filler metal has an important bearing on the design of a brazed joint. For some base metals, only certain select filler metals will do the job.

The selection of proper joint clearance varies with the filler metal used and can be very critical in some applications. Table 21-2 lists recommended joint clearances for some of the materials used as filler metals where normal mechanical strength is required.

TABLE 21-2

FILLER METAL * AWS-ASTM CLASSIFICATION	RECOMMENDED JOINT - CLEARANCE INCHES (NOTES 1 & 3)	SUGGESTED LIMITING SERVICE TEMPERATURE (°F) FOR CONTINUOUS SERVICE	SUGGESTED MAXIMUM SERVICE TEMPERATURE (°F) FOR SHORT PERIODS
B Cu P Group	.001 to .005	300	300
B Ag Group	.002 to .005	400	500
B Cu Zn Group	.002 to .005	400	500
B Cu	.000 to .002 +	400	900
B Ag Mn	.002 to .005	500	900
B Ni Cr	.002 to .005	1000	2000

*These classifications established in specifications for brazing filler metals, ASTM B260-56T, AWS5.8-56T.

Note 1 - In case of round or tubular members recommended joint clearance shall be radial clearance.

+ Note 2 - For max. strength (using B. Cu) clearance shall be from press fit to 0.000 Max.

Note 3 - Joint clearances are at brazing temperatures.

21.4.9.7 Strength of Joints

The tensile and shear strengths of brazed joints will fall off rapidly for any of the following reasons:

1. When the joint clearance is in excess of 0.005 inches. Maximum strength usually occurs at a joint clearance of 0.002 inches.
2. Improper selection of filler metal.
3. Inadequate bonding or wetting.
4. Flux inclusions.
5. Base metal not up to its maximum possible strength.
6. Mechanical characteristics of the structure which cause uneven stress distribution.



WELDING, BRAZING AND SOLDERING

21.4.9.8 Electrical Conductivity

A brazed joint usually will not add appreciable resistance to a circuit if the recommended joint clearances are used. Lap joints are recommended and a length of lap of at least $1\frac{1}{2}$ times the thickness of the thinner member usually will give a resistance approximately equal to an equal length of solid copper. Longer laps will provide even lower resistance.

21.4.9.9 Base Metals

Steel (Low Carbon and Low Alloy) - In general steel with carbon content up to .04 max which is free of scale, heavy oxide, dirt, grease, or foreign material can be brazed. Hot rolled alloy steel containing low percentages of nickel, chromium, molybdenum, tungsten, vanadium, and cobalt may also be brazed. However, the brazing operation is not recommended for the heat-treated grades of low alloy steel where tensile strength in excess of 100,000 psi is required or where heat treatment above 1200 F is necessary.

Copper alloy and silver alloy filler metals with copper content between 30 and 55 percent may be used to join carbon or low alloy steel to itself or to stainless steel, yellow or red brass.

Stainless Steel - Stainless steel is usually brazed with a silver alloy filler metal having a melting point around 1200°F. Nickel-bearing silver-brazing alloys, should be used when brazing some austenitic stainless steels (such as AISI type 302, 316, 340, etc.) if reasonable corrosion resistance is to be obtained. Low brazing temperature, rapid heating, and absence of stress in the work during brazing is important. If corrosion resistance is required after brazing specify one of the materials made of AISI type 321 or 347.

Copper and Copper Alloys, General - Copper and copper alloys are usually brazed with silver alloy filler metal having flow temperature in the range of 1150 to 1600°F. Commercial tough pitch copper should not be used when hydrogen gas is given off, such as in a torch flame, reducing atmosphere in a furnace, etc. In cases when a slight amount of hydrogen is involved during the brazing process, use deoxidized copper. When a hydrogen atmosphere is needed, use material made of oxygen free high conductivity copper.

When strength is important, consideration must be given to the fact that cold-worked copper will anneal at brazing temperatures.

Phosphor Bronze - All grades of phosphor bronze can be brazed with silver alloy filler metals. The higher melting bronzes can be brazed with brass alloy filler metals. When the tin content is high or there are appreciable lead additions, adequate flux protection is necessary.

WELDING, BRAZING AND SOLDERING

21.4.9.9 (Contd)

Nickel and Nickel Alloys - Silver alloy filler metals are frequently used to braze nickel and nickel alloys. To avoid softening of the base metal, the lower melting point alloys, which keep brazing temperatures below approximately 750°C, are preferred. Filler metals containing phosphorus should never be used on nickel or nickel alloys.

The high-nickel alloys, particularly Monel, are subject to stress cracking in the presence of molten low-melting-point filler metals such as those containing cadmium, zinc, and silver. Severely cold-worked parts should be annealed before brazing, and the parts should not be subjected to stress during the brazing operation.

Aluminum and Aluminum Alloys - Aluminum and aluminum alloys may be brazed to themselves but are not recommended for brazing to other metals. Special fluxes, filler metal, and techniques have been developed for brazing commercially pure aluminum, aluminum-manganese alloys, and the aluminum-magnesium-silicon alloys. Techniques and filler metals have not been developed for commercially brazing the aluminum-copper, aluminum-zinc or aluminum-silicon cast or wrought materials.

Various forms of the lap joint are used, rather than the butt or scarf joint. Clearances of .006 to .010 inch are suitable for laps less than $\frac{1}{4}$ inch long; clearance up to .025 inch are used for longer laps. Press or tighter fits must be avoided. Closed assemblies should be designed to provide for the escape of gases during brazing.

21.5 REFERENCE LIST

This paragraph contains a listing of KSC specifications related to welding and brazing. It is intended to be used by the designer for guidance only, and does not imply mandatory usage.

KSC-SPEC-Z-0001	Pipe, 36% Nickel, Iron Base (Invar 36), Specification for
KSC-SPEC-Z-0002	Welding, Aluminum Alloy Pipe, Tubing and Associated Fittings, Specification for
KSC-SPEC-Z-0003	Welding, Stainless Steel and Invar 36 Pipe, Tubing and Associated Fittings, Specification for
KSC-SPEC-Z-0004	Welding, Structural, Carbon Steel, Stainless Steel, Low Alloy Steel, and Aluminum Alloys, Specification for



WELDING, BRAZING AND SOLDERING

21.5 (Contd)

KSC-SPEC-Z-0005	Brazing, Steel, Copper, Aluminum, Nickel, and Magnesium Alloys, Specification for
KSC-SPEC-Z-0006	Induction Brazing, Aerospace Tubing, Fittings, Specification for
KSC-SPEC-Z-0007A	Tubing, Steel, Corrosion Resistant, Types 304 and 316, Seamless, Annealed, Specification for
KSC-SPEC-Z-0008	Fabrication and Installation of Tube Assemblies and Installation of Fittings and Fitting Assemblies, Specification for
KSC-SPEC-Z-0009	Fittings, Tube Lubrication, Application of, Specification for
KSC-SPEC-Z-0010	Welding, T-1 and T-1 Type A and Type B, Structural Steels, Specification for
KSC-SPEC-Z-0016	Welding, Pipe, Automatic, Specification for

American Society of Mechanical Engineers, ASME

Boiler and Pressure Vessel Code
Section IX - Welding Qualifications
Section VIII - Pressure Vessels

American Welding Society, AWS

D2.0 - Specification for Welded Highway and Railway Bridges

D1.1 - Code for Welding in Building Construction

THREADS AND THREADED FASTENERS

22.1 INTRODUCTION

This section contains information necessary to describe and define the common hardware and fasteners used with Ground Support Equipment. The section also describes the machining practices and tools associated with hardware and fastener applications.

22.2 THREAD DESIGNATIONS

The drawing designation for external and internal threads must include the diameter, number of threads per inch, and the fit classification.

Unified threads have substantially the same thread form and are mechanically interchangeable with American National Standard Threads.

The letters A and B identify threads conforming to the principles on which unified threads are based. Some of the A and B threads are not unified. Furthermore, "A" identifies external threads and "B" identifies internal threads.

"U," as prefix to a thread designation, indicates that the thread corresponds to the British and Canadian threads of that size and pitch.

The numerals 1, 2, and 3 refer to the limit or tolerance class.

For threads on fasteners, including screws, bolts, and nuts of all sizes, classes 2A and 2B should be used.

When it is necessary to have a thread differing from standards in a dimensional detail, the thread is designated as a modified thread, and the modified dimension should be shown.

Example: 1/4-20 UNC-2A MODIFIED

$$\text{Major Dia} = \frac{.2489}{.2449}$$

Left-hand threads shall be indicated by adding "LH" to the thread designation.

Example: 1/4-20 UNC-2A-LH

 THREADS AND THREADED FASTENERS

22.2 (Contd)

The maximum axial looseness between a National Standard bolt and nut may be calculated as follows:

$$\begin{aligned} \text{Let } E &= \text{Max End Play} \\ E &= .5774 (\text{Max Int PD} - \text{Min Ext PD}) \end{aligned}$$

22.2.1 SPECIAL THREADS (NS)

When standard threads (unified) will not meet design requirements, the selected special threads listed in table IV.12 of 1957 Supplement of H28 should be considered.

However, if the selected specials listed in that table are not suitable, limiting dimensions of the desired threads must be calculated in accordance with par. 6, page 100, of the above document.

22.2.1.1 Method of Designating

For all "NS" (National Special) threads, specifications of the thread class and pitch-diameter limits are required. In addition, the specification of the length of engagement is required.

Example: 1/4-24 NS-3A

$$\text{PD} \begin{array}{r} .2229 \\ \hline .2198 \end{array}$$

Length of Engagement .875 min

22.3 THREAD SERIES

22.3.1 UNIFIED COARSE-THREAD SERIES

This series, UNC, is generally utilized for the bulk production of bolts, screws, nuts, and other general engineering applications. It is used in general applications for threading into lower-tensile-strength materials such as cast iron, mild steel, and softer materials (bronze, brass, aluminum, magnesium and plastics) to obtain the optimum resistance to stripping of the internal thread. It is applicable for rapid assembly or disassembly, or if corrosion or slight damage is possible.

THREADS AND THREADED FASTENERS

22.3.2 UNIFIED FINE-THREAD SERIES

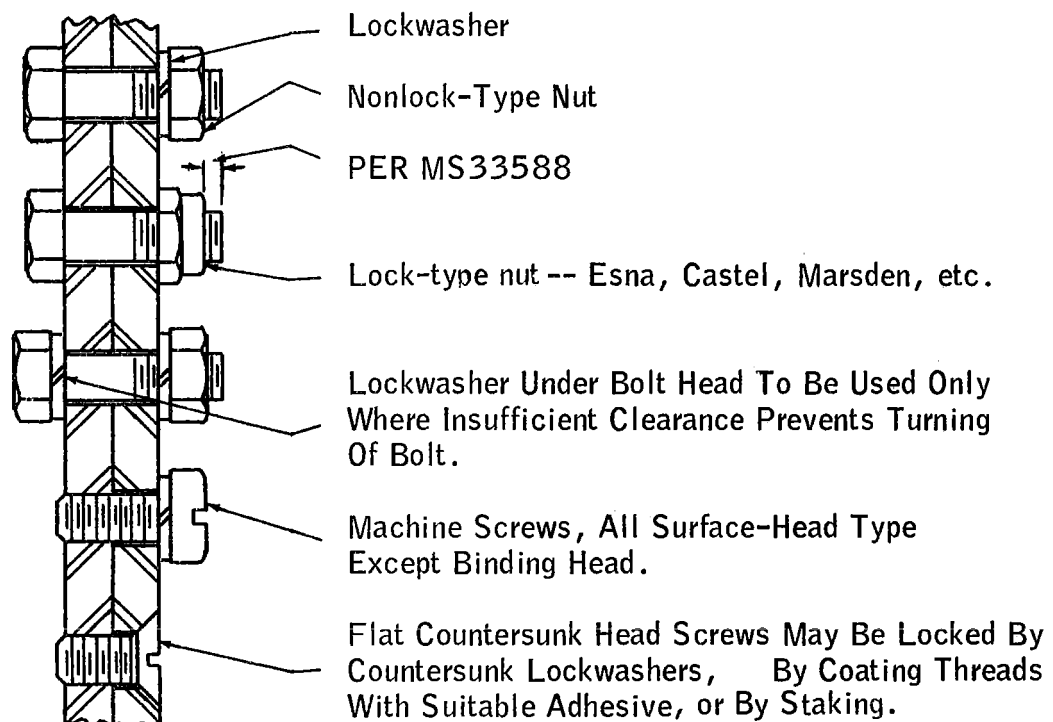
This series, UNF, is suitable for the production of bolts, screws, nuts and other applications where the coarse series is not applicable. External threads of this series have greater tensile stress area than comparable sizes of the coarse series. The fine series is suitable when the resistance to stripping of both external and mating internal threads equals or exceeds the tensile load-carrying capacity of the externally threaded member. It is also used where the length of engagement is short, where a smaller lead angle is desired, or where the wall thickness demands a fine pitch. It may also be used for threading into lower-strength materials where maximum strength of the external thread is not required; otherwise, the length of engagement must be selected to meet the above required strength conditions.

22.3.3 UNIFIED EXTRA-FINE-THREAD SERIES

This series, UNEF, is applicable where even finer pitches of threads are desirable for short lengths of engagement and for thin-walled tubes, nuts, ferrules, or couplings. It is also generally applicable under the conditions stated above for the fine threads.

22.4 TYPICAL APPLICATION OF THREADED FASTENERS

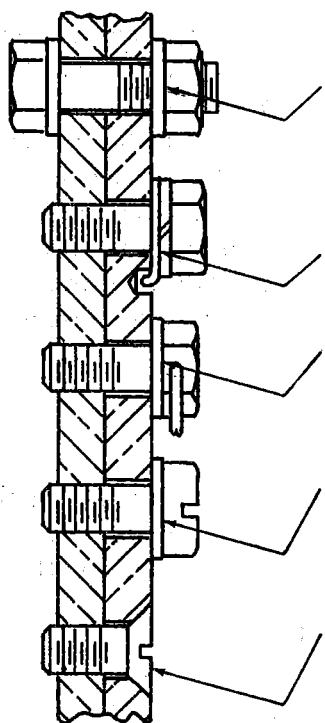
22.4.1 FERROUS METALS AND TITANIUM ADJACENT MATERIAL





THREADS AND THREADED FASTENERS

22.4.2 NONFERROUS AND NONMETALLIC ADJACENT MATERIAL



Plain Washer Required Under All Types Of Nuts. Also Required Under Head Of Screws Securing Cover Plates And Under Bolt And Screw Heads For Nonmetallic Adjacent Materials.

Anchored Steel Plate, Washer Seat, Straddle Lockwasher, or Steel Insert On Which Lockwasher Rests.

Plain Washer and Safety Wire Per MS33540.

Plain Washer Required Under Head Of All Types Of Machine Screws. May Be Locked By Coating Threads With Suitable Adhesive.

Flat Countersunk Head Screws And Set Screws May Be Locked By Coating Threads With Suitable Adhesive, or By Staking When Adjacent Material Is Metallic.

THREADS AND THREADED FASTENERS

22.5 INTERNAL AND EXTERNAL THREAD SIZES

22.5.1 CLASS 2B - INTERNAL THREADS

Size	Thread Symbol	Minor diameter		Pitch diameter		Major diameter Min
		Min	Max	Min	Max	
0-80	NF-2B	.0465	.0514	.0519	.0542	.0600
1-64	NC-2B	.0561	.0623	.0629	.0655	.0730
1-72	NF-2B	.0580	.0635	.0640	.0665	.0730
2-56*	NC-2B	.0667	.0737	.0744	.0772	.0860
2-64	NF-2B	.0691	.0753	.0759	.0786	.0860
3-48	NC-2B	.0764	.0845	.0855	.0885	.0990
3-56	NF-2B	.0797	.0865	.0874	.0902	.0990
4-40*	NC-2B	.0849	.0939	.0958	.0991	.1120
4-48	NF-2B	.0894	.0968	.0985	.1016	.1120
5-40	NC-2B	.0979	.1062	.1088	.1121	.1250
5-44	NF-2B	.1004	.1079	.1102	.1134	.1250
6-32*	NC-2B	.1040	.1140	.1177	.1214	.1380
6-40	NF-2B	.1110	.1190	.1218	.1252	.1380
8-32*	NC-2B	.1300	.1390	.1437	.1475	.1640
8-36	NF-2B	.1340	.1420	.1460	.1496	.1640
10-24	NC-2B	.1450	.1560	.1629	.1672	.1900
10-32*	NF-2B	.1560	.1640	.1697	.1736	.1900
12-24	NC-2B	.1710	.1810	.1889	.1933	.2160
12-28	NF-2B	.1770	.1860	.1928	.1970	.2160
1/4-20*	UNC-2B	.1960	.2070	.2175	.2223	.2500
1/4-28	UNF-2B	.2110	.2200	.2268	.2311	.2500
5/16-18*	UNC-2B	.2520	.2650	.2764	.2817	.3125
5/16-24	UNF-2B	.2670	.2770	.2854	.2902	.3125
3/8-16*	UNC-2B	.3070	.3210	.3344	.3401	.3750
3/8-24	UNF-2B	.3300	.3400	.3479	.3528	.3750
7/16-14	UNC-2B	.3600	.3760	.3911	.3972	.4375
7/16-20	UNF-2B	.3830	.3950	.4050	.4104	.4375
1/2-13*	UNC-2B	.4170	.4340	.4500	.4565	.5000
1/2-20	UNF-2B	.4460	.4570	.4675	.4731	.5000
9/16-12	UNC-2B	.4720	.4900	.5084	.5152	.5625
9/16-18	UNF-2B	.5020	.5150	.5264	.5323	.5625
5/8-11*	UNC-2B	.5270	.5460	.5660	.5732	.6250
5/8-18	UNF-2B	.5650	.5780	.5889	.5949	.6250

*Preferred



Ground Support Equipment

THREADS AND THREADED FASTENERS

22.5.1 (Contd)

Size	Thread Symbol	Minor diameter		Pitch diameter		Major diameter Min
		Min	Max	Min	Max	
3/4-10*	UNC-2B	.6420	.6630	.6850	.6927	.7500
3/4-16	UNF-2B	.6820	.6960	.7094	.7159	.7500
7/8-9	UNC-2B	.7550	.7780	.8028	.8110	.8750
7/8-14	UNF-2B	.7980	.8140	.8286	.8356	.8750
1-8*	UNC-2B	.8650	.8900	.9188	.9276	1.0000
1-12	UNF-2B	.9100	.9280	.9459	.9535	1.0000
1-1/8-7	UNC-2B	.9700	.9980	1.0322	1.0416	1.1250
1-1/8-8	N-2B	.9900	1.0150	1.0438	1.0528	1.1250
1-1/8-12	UNF-2B	1.0350	1.0530	1.0709	1.0787	1.1250
1-1/4-7	UNC-2B	1.0950	1.1230	1.1572	1.1668	1.2500
1-1/4-8*	N-2B	1.1150	1.1400	1.1688	1.1780	1.2500
1-1/4-12	UNF-2B	1.1600	1.1780	1.1959	1.2039	1.2500
1-3/8-6	N-2B	1.1950	1.2250	1.2667	1.2771	1.3750
1-3/8-8	N-2B	1.2400	1.2650	1.2938	1.3031	1.3750
1-3/8-12	UNF-2B	1.2850	1.3030	1.3209	1.3291	1.3750
1-1/2-6	UNC-2B	1.3200	1.3500	1.3917	1.4022	1.5000
1-1/2-8*	N-2B	1.3650	1.3900	1.4188	1.4283	1.5000
1-1/2-12	UNF-2B	1.4100	1.4280	1.4459	1.4542	1.5000
1-3/4-5	UNC-2B	1.5340	1.5680	1.6201	1.6317	1.7500
1-3/4-8	N-2B	1.6150	1.6400	1.6688	1.6786	1.7500
2-4-1/2	UNC-2B	1.7590	1.7950	1.8557	1.8681	2.0000
2-8*	N-2B	1.8650	1.8900	1.9188	1.9289	2.0000
2-1/8-8	N-2B	1.9900	2.0150	2.0438	2.0540	2.1250
2-1/4-1/2	UNC-2B	2.0090	2.0450	2.1057	2.1183	2.2500
2-1/4-8	N-2B	2.1150	2.1400	2.1688	2.1792	2.2500
2-1/2-4	UNC-2B	2.2290	2.2670	2.3376	2.3511	2.5000
2-1/2-8*	N-2B	2.3650	2.3900	2.4188	2.4294	2.5000
2-3/4-4	UNC-2B	2.4790	2.5170	2.5876	2.6013	2.7500
2-3/4-8	N-2B	2.6150	2.6400	2.6688	2.6796	2.7500
3-4	UNC-2B	2.7290	2.7670	2.8376	2.8515	3.0000
3-8	N-2B	2.8650	2.8900	2.9188	2.9299	3.0000
3-1/4-4	UNC-2B	2.9790	3.0170	3.0876	3.1017	3.2500
3-1/4-8	N-2B	3.1150	3.1400	3.1688	3.1801	3.2500
3-1/2-4	UNC-2B	3.2290	3.2670	3.3376	3.3519	3.5000
3-1/2-8	N-2B	3.3650	3.3900	3.4188	3.4303	3.5000
3-3/4-4	UNC-2B	3.4790	3.5170	3.5876	3.6021	3.7500
4-4	UNC-2B	3.7290	3.7670	3.8376	3.8523	4.0000
4-8	N-2B	3.8650	3.8900	3.9188	3.9307	4.0000

*Preferred

THREADS AND THREADED FASTENERS

22.5.1 (Contd)

Size	Thread symbol	Minor diameter		Pitch diameter		Major diameter Min
		Min	Max	Min	Max	
4-1/4-8	N-2B	4.1150	4.1400	4.1688	4.1809	4.2500
4-1/2-8	N-2B	4.3650	4.3900	4.4188	4.4310	4.5000
4-3/4-8	N-2B	4.6150	4.6400	4.6688	4.6812	4.7500
5-8	N-2B	4.8650	4.8900	4.9188	4.9314	5.0000
5-1/4-8	N-2B	5.1150	5.1400	5.1688	5.1815	5.2500
5-1/2-8	N-2B	5.3650	5.3900	5.4188	5.4317	5.5000
5-3/4-8	N-2B	5.6150	5.6400	5.6688	5.6818	5.7500
6-8	N-2B	5.8650	5.8900	5.9188	5.9320	6.0000

* Preferred

22.5.2 CLASS 2A - EXTERNAL THREADS

Size	Thread symbol	Allow- ance	Major diameter			Pitch diameter		Minor dia (1) Max
			(1) Max	(2) Min	(3) Min	(1) Max	Min	
0-80	NF-2A	.0005	.0595	.0563	--	.0514	.0496	.0442
1-64	NC-2A	.0006	.0724	.0686	--	.0623	.0603	.0532
1-72	NF-2A	.0006	.0724	.0689	--	.0634	.0615	.0554
2-56*	NC-2A	.0006	.0854	.0813	--	.0738	.0717	.0635
2-64	NF-2A	.0006	.0854	.0816	--	.0753	.0733	.0662
3-48	NC-2A	.0007	.0983	.0938	--	.0848	.0825	.0727
3-56	NF-2A	.0007	.0983	.0942	--	.0867	.0845	.0764
4-40*	NC-2A	.0008	.1112	.1061	--	.0950	.0925	.0805
4-48	NF-2A	.0007	.1113	.1068	--	.0978	.0954	.0857
5-40	NC-2A	.0008	.1242	.1191	--	.1080	.1054	.0935
5-44	NF-2A	.0007	.1243	.1195	--	.1095	.1070	.0964
6-32*	NC-2A	.0008	.1372	.1312	--	.1169	.1141	.0989
6-40	NF-2A	.0008	.1372	.1321	--	.1210	.1184	.1065
8-32*	NC-2A	.0009	.1631	.1571	--	.1428	.1399	.1248
8-36	NF-2A	.0008	.1632	.1577	--	.1452	.1424	.1291
10-24	NC-2A	.0010	.1890	.1818	--	.1619	.1586	.1379
10-32*	NF-2A	.0009	.1891	.1831	--	.1688	.1658	.1508
12-24	NC-2A	.0010	.2150	.2078	--	.1879	.1845	.1639
12-28	NF-2A	.0010	.2150	.2085	--	.1918	.1886	.1712

*Preferred



Ground Support Equipment

THREADS AND THREADED FASTENERS

22.5.2 (Contd)

Size	Thread symbol	Allow- ance	Major Diameter			Pitch Diameter		Minor Dia Max (1)
			(1) Max	(2) Min	(3) Min	(1) Max	Min	
1/4-20*	UNC-2A	.0011	.2489	.2408	.2367	.2164	.2127	.1876
1/4-28	UNF-2A	.0010	.2490	.2425	--	.2258	.2225	.2052
5/16-18*	UNC-2A	.0012	.3113	.3026	.2982	.2752	.2712	.2431
5/16-24	UNF-2A	.0011	.3114	.3042	--	.2843	.2806	.2603
3/8-16*	UNC-2A	.0013	.3737	.3643	.3595	.3331	.3287	.2970
3/8-24	UNF-2A	.0011	.3739	.3667	--	.3468	.3430	.3228
7/16-14	UNC-2A	.0014	.4361	.4258	.4206	.3897	.3850	.3485
7/16-20	UNF-2A	.0013	.4362	.4281	--	.4037	.3995	.3749
1/2-13*	UNC-2A	.0015	.4985	.4876	.4822	.4485	.4435	.4041
1/2-20	UNF-2A	.0013	.4987	.4906	--	.4662	.4619	.4374
9/16-12	UNC-2A	.0016	.5609	.5495	.5437	.5068	.5016	.4587
9/16-18	UNF-2A	.0014	.5611	.5524	--	.5250	.5205	.4929
5/8-11*	UNC-2A	.0016	.6234	.6113	.6052	.5644	.5589	.5119
5/8-18	UNF-2A	.0014	.6236	.6149	--	.5875	.5828	.5554
3/4-10*	UNC-2A	.0018	.7482	.7353	.7288	.6832	.6773	.6255
3/4-16	UNF-2A	.0015	.7485	.7391	--	.7079	.7029	.6718
7/8-9	UNC-2A	.0019	.8731	.8592	.8523	.8009	.7946	.7368
7/8-14	UNF-2A	.0016	.8734	.8631	--	.8270	.8216	.7858
1-8*	UNC-2A	.0020	.9980	.9830	.9755	.9168	.9100	.8446
1-12	UNF-2A	.0018	.9982	.9868	--	.9441	.9382	.8960
1-1/8-7	UNC-2A	.0022	1.1228	1.1064	1.0982	1.0300	1.0228	.9475
1-1/8-8	N-2A	.0021	1.1229	1.1079	1.1004	1.0417	1.0348	.9695
1-1/8-12	UNF-2A	.0018	1.1232	1.1118	--	1.0691	1.0631	1.0210
1-1/4-7	UNC-2A	.0022	1.2478	1.2314	1.2232	1.1550	1.1476	1.0725
1-1/4-8*	N-2A	.0021	1.2479	1.2329	1.2254	1.1667	1.1597	1.0945
1-1/4-12	UNF-2A	.0018	1.2482	1.2368	--	1.1941	1.1879	1.1460
1-3/8-6	UNC-2A	.0024	1.3726	1.3544	1.3453	1.2643	1.2563	1.1681
1-3/8-8	N-2A	.0022	1.3728	1.3578	1.3503	1.2916	1.2844	1.2194
1-3/8-12	UNF-2A	.0019	1.3731	1.3617	--	1.3190	1.3127	1.2709
1-1/2-6	UNC-2A	.0024	1.4976	1.4794	1.4703	1.3893	1.3812	1.2931
1-1/2-8*	N-2A	.0022	1.4978	1.4828	1.4753	1.4166	1.4093	1.3444
1-1/2-12	UNF-2A	.0019	1.4981	1.4867	--	1.4440	1.4376	1.3959
1-3/4-5	UNC-2A	.0027	1.7473	1.7268	1.7165	1.6174	1.6085	1.5019
1-3/4-8	N-2A	.0023	1.7477	1.7327	1.7252	1.6665	1.6590	1.5943
2-4-1/2	UNC-2A	.0029	1.9971	1.9751	1.9641	1.8528	1.8433	1.7245
2-8*	N-2A	.0023	1.9977	1.9827	1.9752	1.9165	1.9087	1.8443
2-1/8-8	N-2A	.0024	2.1226	2.1076	2.1001	2.0414	2.0335	1.9692

*Preferred

THREADS AND THREADED FASTENERS

22.5.2 (Contd)

Size	Thread symbol	Allow- ance	Major Diameter			Pitch Diameter		Minor Dia Min (1)
			(1) Max	(2) Min	(3) Min	(1) Max	Min	
2-1/4-4	UNC-2A	.0029	2.2471	2.2251	2.2141	2.1028	2.0931	1.9745
-1/2								
2-1/4-8	N-2A	.0024	2.2476	2.2326	2.2251	2.1664	2.1584	2.0942
2-1/2-4	UNC-2A	.0031	2.4969	2.4731	2.4612	2.3345	2.3241	2.1902
2-1/2-8*	N-2A	.0024	2.4976	2.4826	2.4751	2.4164	2.4082	2.3442
2-3/4-4	UNC-2A	.0032	2.7468	2.7230	2.7111	2.5844	2.5739	2.4401
2-3/4-8	N-2A	.0025	2.7475	2.7325	2.7250	2.6663	2.6580	2.5941
3-4	UNC-2A	.0032	2.9968	2.9730	2.9611	2.8344	2.8237	2.6901
3-8	N-2A	.0026	2.9974	2.9824	2.9749	2.9162	2.9077	2.8440
3-1/4-4	UNC-2A	.0033	3.2467	3.2229	3.2110	3.0843	3.0734	2.9400
3-1/4-8	N-2A	.0026	3.2474	3.2324	3.2249	3.1662	3.1575	3.0940
3-1/2-4	UNC-2A	.0033	3.4967	3.4729	3.4610	3.3343	3.3233	3.1900
3-1/2-8	N-2A	.0026	3.4974	3.4824	3.4749	3.4162	3.4074	3.3440
3-3/4-4	UNC-2A	.0034	3.7466	3.7228	3.7109	3.5842	3.5730	3.4399
3-3/4-8	N-2A	.0027	3.7473	3.7323	3.7248	3.6661	3.6571	3.5939
4-4	UNC-2A	.0034	3.9966	3.9728	3.9609	3.8342	3.8229	3.6899
4-8	N-2A	.0027	3.9973	3.9823	3.9748	3.9161	3.9070	3.8439
4-1/4-8	N-2A	.0028	4.2472	4.2322	4.2247	4.1660	4.1567	4.0938
4-1/2-8	N-2A	.0028	4.4972	4.4822	4.4747	4.4160	4.4066	4.3438
4-3/4-8	N-2A	.0029	4.7471	4.7321	4.7246	4.6659	4.6564	4.5937
5-8	N-2A	.0029	4.9971	4.9821	4.9746	4.9159	4.9062	4.8437
5-1/4-8	N-2A	.0029	5.2471	5.2321	5.2246	5.1659	5.1561	5.0937
5-1/2-8	N-2A	.0030	5.4970	5.4820	5.4745	5.4158	5.4059	5.3436
5-3/4-8	N-2A	.0030	5.7470	5.7320	5.7245	5.6658	5.6558	5.5936
6-8	N-2A	.0030	5.9970	5.9820	5.9745	5.9158	5.9056	5.8436

*Preferred

Footnotes: (applicable to paragraph 22.5.2 only)

1. The maximum dimensions of threads which are electroplated or have coatings of similar thickness will be increased by the amount of the allowance.
2. For semifinished and finished screws and bolts, threaded portion only.
3. For unfinished hot-rolled material threaded portion only.



Ground Support Equipment

THREADS AND THREADED FASTENERS

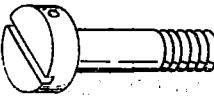
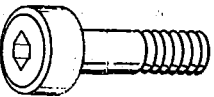
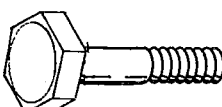
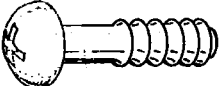
22.6 COMMON HARDWARE FOR GROUND-SUPPORT EQUIPMENT

The following pages reference commonly used screws, nuts, and washers as applied to Ground-Support Equipment.

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THREADS AND THREADED FASTENERS

22.6 (Contd)

Type of Fastener	Basic Designation				Remarks
	Steel	Cad Pl	Cor Res	Stl Other	
 Screw, Machine, Drilled Fillister Hd, Slotted Coarse Thread Fine Thread	55,000 psi		70,000 psi		Nonstructural: General Purpose Where safety Wire is Req'd.
	MS 35265		MS 35275		
	MS 35266		MS 35276		
 Screw, Cap, Hex Soc Head Undrilled and drilled plain & self-locking Coarse Thread Fine Thread	160,000 psi		80,000 psi		Structural Use where wrench clearance is limited or flush mounting is required.
	NAS 1352		NAS 1352		
	NAS 1351		NAS 1351		
 Screw, Cap, Hex Head Coarse Thread Fine Thread	90,000 to 120,000 psi		70,000 psi		Structural: General Purpose
	MS 90725		MS 35307		
	MS 90726		MS 35308		
 Screw, Tapping, Rd Hd	AN 530		AN 530		Nameplates, Permanent fastenings where applicable.

SECTION 22

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DATE 15 Sept. 1965

KSC








MANUAL

Ground Support Equipment

THREADS AND THREADED FASTENERS

22.6 (Contd)

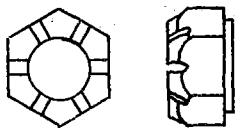
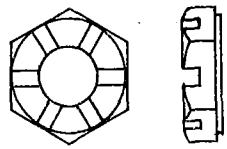
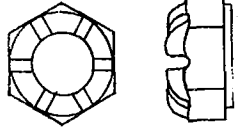
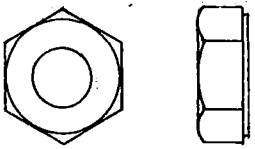
Type of Fastener	Basic Designation			Remarks
	Steel	Cad PI	Cor Res Stl	
 Setscrew Self-locking Hex Soc, Nonlock				*250° F Max
	*NAS 1081		*NAS 1081	
	AN 565		AN 565	

Type of Fastener	Basic Designation			Remarks
	Steel	Cad PI	Cor Res Stl	
 Washer, Flat				Alum. Brass AN 960
	AN 960		AN 960	
 Washer, Lock, Split Helical				Phos Brz
	MS 35338		MS 35338	MS 35338
 Washer, Lock, Flat Internal Tooth				Phos Brz
	MS 35333		MS 35333	MS 35333
 Washer, Lock, Flat External Tooth				Phos Brz
	MS 35335		MS 35335	MS 35335

REVISED

THREADS AND THREADED FASTENERS


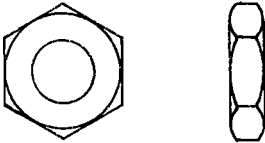
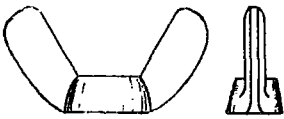
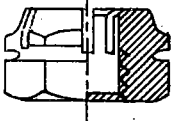
22.6 (Contd)

Type of Fastener	Basic Designation			Remarks
	Steel	Cor Res Stl	Other	
 Nut, Castellated Fine Thread	AN 310	AN 310	Alum. AN 310	
 Nut, Castle Shear Fine Thread	AN 320	AN 320	Alum. AN 320	
 Nut, Slotted Coarse Thread Fine Thread	Cad Plated MS 35692 MS 35692	MS 35692 MS 35692	Brass MS 35692 MS 35692	
 Nut, Plain Hex Coarse Thread Fine Thread	Cad Plated MS 35649 MS 35650	MS 35649 MS 35650	Brass MS 35649 MS 35650	Sizes #2 through #10



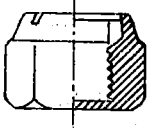
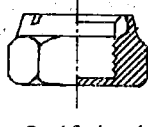
THREADS AND THREADED FASTENERS

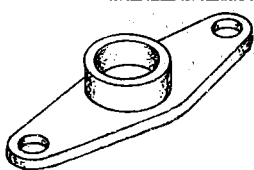
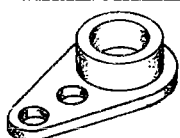
22.6 (Contd)

Type of Fastener	Basic Designation			Remarks
	Steel	Cor Res Stl	Other	
 Nut, Plain Hex Coarse Thread Fine Thread	Cad Plate MS 35690 MS 35690	 MS 35690 MS 35690	 MS 35690 MS 35690	1/4" through 3"
 Nut, Jam Coarse Thread Fine Thread	 MS 35691 MS 35691	 MS 35691 MS 35691	Brass MS 35691 MS 35691	
 Wing Nut Coarse Thread Fine Thread	Cad Plate MS 35425 MS 35426	 	Brass MS 35425 MS 35426	
 Nut, Self-locking Coarse Thread Fine Thread	 MS 21045 MS 21045	 MS 21045 MS 21045	 	450° F Max NC in #4 through #8 only.

THREADS AND THREADED FASTENERS

22.6 (Contd)

Type of Fastener	Basic Designation			Remarks
	Steel	Cor Res Stl	Other	
 Nut, Self-locking Coarse Thread Fine Thread	MS 21042 MS 21042			NC in #2 through #8 only
 Nut, Self-locking Thin Coarse Thread Fine Thread	MS 21083 MS 21083	MS 21083 MS 21083	Copper or Alum. MS 21083 MS 21083	NC in #4 through #8 only

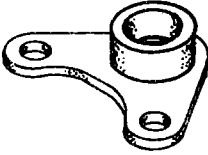
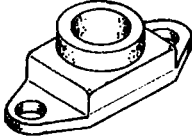
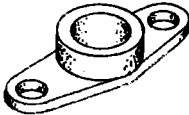
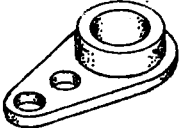
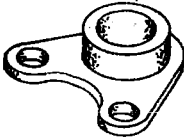
Type of Fastener	Basic Designation			Remarks
	Steel Cad Pl	Cor Res Stl	Other	
 Two Lug-Fixed	450° F MS 21069	450°F & 800°F MS 21070		Use where manufacturing tolerances do not require lateral nut float to compensate for misalignment.
 One Lug-Fixed	550° F NAS 682	800° F NAS 682		



Ground Support Equipment

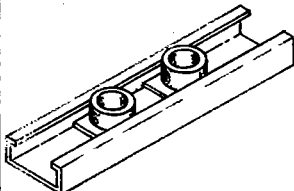
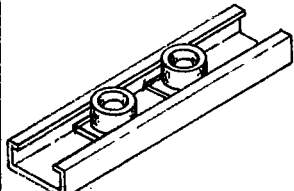
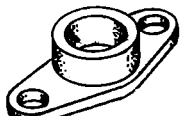
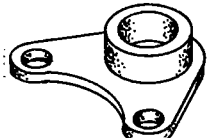
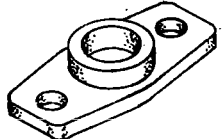
THREADS AND THREADED FASTENERS

22.6 (Contd)

Type of Fastener	Basic Designation			Remarks
	Steel, Cad Pl	Cor Res Stl	Other	
 Corner Type-Fixed	550° F NAS 684	800° F NAS 684		Use where manufacturing tolerances do not require lateral nut float to compensate for misalignment.
 Two Lug-Floating	550° F NAS 686	800° F NAS 686		Use where manufacturing tolerances require lateral nut float to compensate for misalignment.
 Two Lug-Fixed 100° Countersunk	550° F AN 361	550° F AN 361	250° F High Strength Alum. Alloy AN 373	Inactive see MS 21049 & MS 21050
 One Lug-Fixed 100° Countersunk	550° F NAS 683	800° F NAS 683		Use in dimpled bolt or screw-hole applications.
 Corner Type-Fixed 100° Countersunk	550° F NAS 685	800° F NAS 685		

THREADS AND THREADED FASTENERS

22.6 (Contd)

Type of Fastener	Basic Designation			Remarks
	Steel, Cad Pl	Cor Res Stl	Other	
 Gang Channel Plain	NAS 1034 through NAS 1038	NAS 1034 through NAS 1038	Al Alloy NAS 1034 through NAS 1038	Used in lieu of anchor nuts where uniform nut spacing permits.
 Gang Channel- 100° countersunk	NAS 1039 through NAS 1041	NAS 1039 through NAS 1041	Al Alloy NAS 1039 through NAS 1041	
 Miniature Two Lug-Fixed	550°F NAS 697	800°F NAS 697		
 Miniature Corner Type-Fixed	500° NAS 698	800°F NAS 698		These anchor nuts are miniature in regard to the reduced rivet spacing only. Use in lieu of conventional anchor nuts to save weight.
 Miniature Two Lug-Floating	500°F NAS 1068	800°F NAS 1068		



THREADS AND THREADED FASTENERS

22.7 SELF-TAPPING SCREWS

Thread-cutting screws AN530 may be used where construction is improved thereby and where they will not require loosening or removal during operation or maintenance of the equipment. Chips formed by self-tapping screws in through holes shall be removed. Self-tapping, sheet metal screws shall not be used. Where practicable, anchor nuts or nut plates shall be used for thread engagement in sheet metal.

22.7.1 INSTALLATION AND LIMITATION FOR USAGE OF SELF-TAPPING SCREWS

The use of self-tapping screws is governed by the following:

22.7.1.1 Limitation For Usage

Self-tapping and sheet metal screws, conforming to Drawing AN530, shall not be used under the following conditions:

- a. As fastenings for the fabrication of primary structure.
- b. Where the joint is subject to rotation which would tend to loosen the screw.
- c. As fastenings for structure or accessories where failure might result in danger or damage.
- d. Where required to cut their own threads and are subsequently subject to removal.
- e. Where subject to corrosive mediums, such as exhaust gases, etc.

22.7.1.2 Installation

The length of screw installed in sheet material shall be such that at least two threads of the grip extend beyond the assembly.

Drill hole sizes for AN530 screws shall conform to AND10325.

If sheet material is to be fastened to castings or other types of structure by means of self-tapping screws, clearance holes should be drilled in the sheet to permit drawing the parts tightly together.

Self-tapping screws used in aluminum alloys shall be installed with a phenolic or aluminum washer. The washer and screw shall be coated with zinc-chromate paste before insertion to completely seal the connection.

THREADS AND THREADED FASTENERS

22.8 HEADLESS SETSCREWS

Setscrews shall be used only where uniquely required by design of the equipment. Setscrews, when used, shall be of the hardened, hexagon-socket type and preferably shall be number 6 or number 10. Cone-point setscrews may be used where the engaging surfaces are suitably countersunk to receive the point. Otherwise cup-point setscrews shall be used. Flat surfaces shall be provided for engagement of cup-point screws when the part is not adjustable in angular relationship to the shaft on which it is secured. When the shaft is not flattened, two setscrews positioned about 90 degrees to 120 degrees displacement shall be used.

The maximum holding power of the cup-point setscrew depends on the following four conditions:

22.8.1 TIGHTENING FORCE

The holding power of setscrews is proportional to the tightening torque applied. The greater the tightening torque, the better the holding power.

22.8.2 CUP DIAMETER IN RELATION TO SHAFT DIAMETER

The minimum-size diameter of the shaft on which a setscrew is used should not be less than four times the cup diameter of the setscrew. Shafting of less than four times the diameter of the setscrew has poor holding characteristics because the whole cup is not imbedded in the shaft. If the whole cup point is imbedded in a round shaft, the holding power will be equal to or greater than the holding power on a flat surface.

22.8.3 SHAFT HARDNESS

Where the hardness of the shaft is equal to or exceeds that of the setscrew, the holding power of the screw is limited to the holding power obtained by friction alone. Hex-socket setscrews are made from alloy steel hardened to Rockwell C45-54.

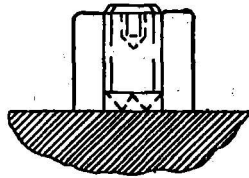
Where the shaft hardness is not equal to or greater than that of the setscrew, the holding-power values do not differ greatly from those for standard soft shafting. On a soft shaft, a deeper indentation is made by the cup point than on a harder shaft. The harder shaft, however, resists shear better; thus, its resistance to slip is equalized.



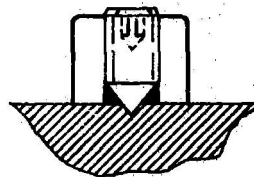
 THREADS AND THREADED FASTENERS

22.8.4 SETSCREW LOCATION

The angle between two setscrews should be kept to a minimum. Two setscrews at 90 degrees are better than two setscrews at 120 degrees.



Cup Point



Cone Point

Headless Setscrews

22.9 CLEARANCE HOLES FOR SCREWS AND BOLTS

(MACHINED PARTS-STABLE MATERIALS)

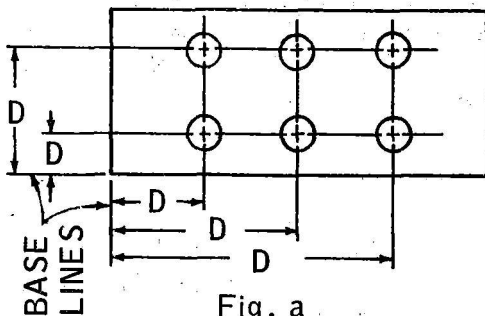


Fig. a

MULTIPLE HOLES FROM B L

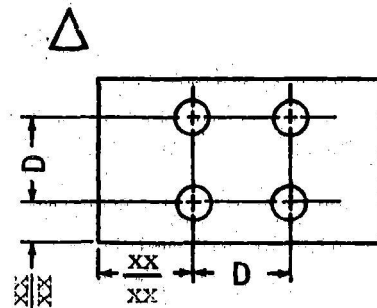


Fig. b

GROUP OF FOUR HOLES

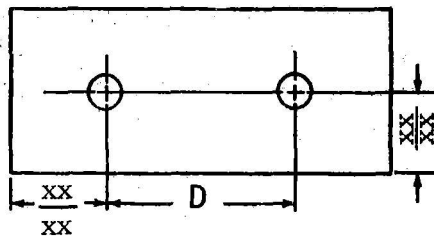


Fig. c

TWO HOLES AT RANDOM



 THREADS AND THREADED FASTENERS

22.9 (Contd)

Screw Size	Screw Dia	Clearance Hole And Drill No.	Tolerance on Center Distance "D"		
			Fig. a*	Fig. b**	Fig. c***
#2	.086	.0995 (#39)	± .003	± .005	± .006
#4	.112	.1285 (#30)	↑ .003	↑ .005	↑ .008
#6	.138	.157 (#22)	↑ .005	↑ .008	↑ .008
#8	.164	.185 (#13)	↑ .005	↑ .008	↑ .010
#10	.190	.213 (#3)	↑ .005	↑ .008	↑ .010
1/4	.250	9/32 DIA	↑ .005	↑ .010	↑ .015
5/16	.312	23/64 ↑	↑ .010	↑ .015	↑ .015
3/8	.375	27/64 ↑	↑ .010	↑ .015	↑ .015
1/2	.500	9/16 ↑	↑ .010	↑ .015	↑ .031
5/8	.625	11/16 ↑	↑ .010	↑ .015	↑ .031
3/4	.750	13/16 ↑	↑ .010	↑ .015	↑ .031
7/8	.875	15/16 ↓	↓ .010	↓ .015	↓ .031
1	1.000	1-3/32 DIA	± .015	± .031	± .031

* For multiple clearance holes between ϕ and ref. base lines applying to both tapped and clearance holes.

** For four holes, between ϕ when location with respect to other surfaces or base lines is not important, applying to both tapped and clearance holes.

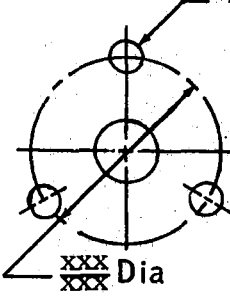
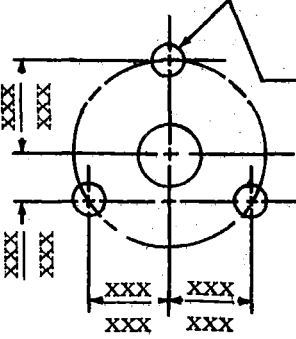
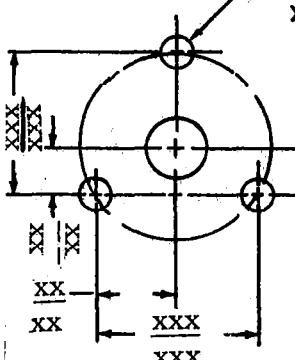
*** For only two holes between ϕ when location with respect to other surfaces or base lines is not important, applying to both tapped and clearance holes.

△ Tolerances for nonstable materials, such as cloth, paper, rubber, etc., should be established for each application with realistic tolerances specified on the drawing.



THREADS AND THREADED FASTENERS

22.10 HOLE SPACING ON A CIRCLE

Requirements	Drawing Notes
<p>a.</p> <p>When holes are equally spaced on a bolt circle with a minimum tolerance on spacings - generally used for retainers, gear lightening holes, caps and covers (to utilize automatic rotary drilling machine). This machine requires hole spacing on 15° increments or multiples thereof (2, 3, 4, 6, 8, 12, 24) and limited to 6" dia. Maximum bolt circle and a 14" dia maximum swing.</p>	 <p>*Tolerance to be equal to or greater than tolerance on bolt circle.</p>
<p>b.</p> <p>When holes must be spaced in accurate relation with center.</p>	
<p>c.</p> <p>When holes bear no relation to center, but alignment requires a minimum tolerance between any two holes.</p>	



 THREADS AND THREADED FASTENERS

22.11 TOLERANCES ON HOLE DIAMETERS

Drill size#	Nominal dia	Min - Max Limits (Metallic)	*Tol Range	Min - Max Limits (Nonmetallic)	*Tol Range
#60	.0400	.039 - .042	+ .002 - .001	.037 - .041	+ .001 - .003
#50	.0700	.069 - .073	+ .003 - .001	.067 - .071	+ .001 - .003
#39	.0995	.098 - .104	+ .004 - .001	.096 - .100	+ .001 - .004
#32	.1160	.115 - .120		.112 - .117	
#30	.1285	.128 - .132		.124 - .130	
#28	.1405	.138 - .146		.136 - .142	
#27	.1440	.142 - .149	+ .005 - .002	.139 - .146	+ .002 - .005
#23	.1540	.152 - .159		.149 - .156	
#22	.1570	.155 - .162		.152 - .159	
#18	.1695	.168 - .174		.146 - .172	
# 9	.1960	.194 - .201		.191 - .198	
# 3	.2130	.211 - .218		.208 - .215	
# 2	.2210	.219 - .226		.216 - .223	
# 1	.2280	.226 - .233		.223 - .230	
(B)	.2380	.236 - .244	+ .006 - .002	.231 - .241	+ .003 - .007
(C)	.2420	.240 - .248		.235 - .245	
1/4	.2500	.248 - .256		.243 - .253	
9/32	.2813	.279 - .287		.274 - .284	
5/16	.3125	.310 - .318		.305 - .316	
23/64	.3594	.357 - .365		.352 - .362	
3/8	.3750	.373 - .381		.368 - .378	
13/32	.4062	.404 - .412		.399 - .409	
27/64	.4219	.420 - .428	+ .008 - .002	.415 - .425	+ .003 - .008
7/16	.4375	.436 - .444		.430 - .440	
1/2	.5000	.498 - .506		.493 - .503	
9/16	.5623	.560 - .570		.554 - .566	
5/8	.6250	.623 - .633	+ .010 - .003	.617 - .628	+ .005 - .010
11/16	.6875	.686 - .696		.680 - .690	
3/4	.7500	.748 - .758		.742 - .753	
13/16	.8125	.810 - .822		.802 - .818	
7/8	.8750	.872 - .885		.865 - .880	
15/16	.9375	.934 - .948		.928 - .942	
1	1.0000	.997 - 1.010		.990 - 1.005	

* Tolerance range applies to drill sizes up to and including the size listed.

Note: Tolerances shown apply to drilled and punched holes.

For hole sizes not listed up to 1" dia the max/min dimension may be established using the tolerance shown in the tol range column.



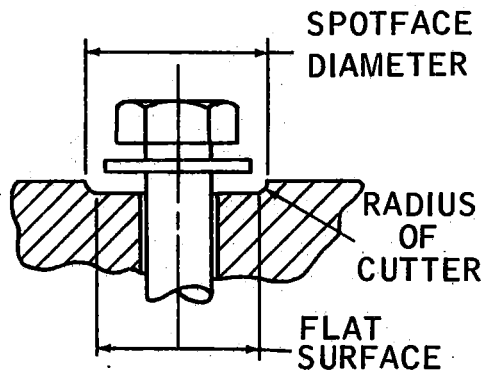
 THREADS AND THREADED FASTENERS

22.11.1 METHOD OF SPECIFYING ON DRAWING

- a. $\frac{.042}{.039}$ (#60) DIA b. $\frac{.318}{.310}$ $\left(\frac{5}{16}\right)$ DIA

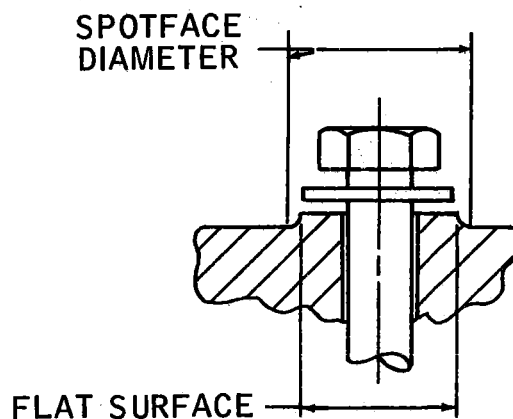
22.12 SPOTFACING

- a. The spotface diameter must be large enough to clear the mating part under all adverse tolerance conditions.
- b. The following values provide minimum spotface for washer or bolt clearance, but do not allow for wrench clearance.



BOLT SIZE	MINIMUM SPOTFACE FOR BOLT OR WASHER CLEARANCE		
	AN BOLTS & NUTS - HEX AN 960 WASHER	MACHINE SCREW WITHOUT WASHER	
		FIL HEAD	ROUND HEAD
#10	9/16	7/16	1/2
1/4	5/8	9/16	5/8
5/16	11/16	21/32	23/32
3/8	3/4	3/4	27/32
7/16	7/8		
1/2	1		
9/16	1 3/16		
5/8	1 3/8		
3/4	1 1/2		
7/8	1 11/16		
1	1 15/16		
1 1/8	2 1/16		
1 1/4	2 3/16		

- c. On raised bosses, the spotface diameter must always be larger than the boss diameter to prevent burrs caused by eccentricity or adverse tolerances.





 THREADS AND THREADED FASTENERS

22.12.1 COUNTERBORE AND SPOTFACE DATA

Diameter of counterbore and spotface shall be a minimum of .08 larger than maximum component involved to allow for .04 radius on tool.

Using Max/Min dimensioning, specify depth of counterbore to suit design.

A reasonable tolerance for counterboring is $-.00 + .02$.

C-bores available are:

3/16, 0.195, 13/64, 7/32, 15/64, 1/4, 17/64, 9/32, 19/64, 5/16, 21/64, 11/32, 23/64, 3/8, 25/64, 13/32, 27/64, 7/16, 1/2, 29/64, 15/32, 31/64, 33/64, 17/32, 9/16, 19/32, 5/8, 41/64, 43/64, 11/16, 45/64, 23/32, 47/64, 3/4, 49/64, 25/32, 13/16, 7/8, 29/32, 15/16, 61/64, 31/32, 1, 1-1/32, 1-1/16, 1-7/64, 1-1/8, 1-5/32, 1-3/16, 1-1/4, 1-9/32, 1-5/16, 1-11/32, 1-3/8, 1-25/64, 1-13/32, 1-7/16, 1-1/2, 1-9/16, 1-5/8, 1-23/32, 1-3/4, 1-13/16, 1-7/8, 1-15/16, 2, 2-1/4, 2-1/2, 3

Typical Method of Specifying:

<u>C-bore</u>		<u>Spotface</u>
$\frac{.38}{.40}$	(3/8) Dia C-bore x .26 deep	$\frac{.50}{.52}$ (1/2) Dia SF
	$\frac{.26}{.28}$	

Judgement should be used to avoid an excessive number of sizes of C-bore on any given piece.

22.13 SCREW-LOCKING METHODS

Locking of screws and bolts may be accomplished by the use of spring lockwashers, or other methods outlined in this section. In general, a plain washer should be used under the lockwasher for any adjacent materials for screws sizes up to including #4.

Tooth lockwashers lock fasteners to component parts of an assembly by displacement or gouging into the adjacent material. This type of lockwasher may be internal or external tooth, depending on design requirements.

Screws may be locked by displacement of material, such as in self-locking nuts, helical coil inserts of the screw lock type, Nilock screws, etc.

Locking by safety wire prevents loosening by properly wiring two or more screws together.

THREADS AND THREADED FASTENERS

22.13.1 SAFETY WIRE

The following data for safety wire should be used as applicable:

<u>Screw size</u>	<u>Wire dia</u>	<u>Dwg ref for wire</u>
#2 and #4	.020	MS 20995C20
#6 and above	.032	MS 20995C32

On the parts list, specify lock wire by the above MS Part No. with quantity as required (AR). On the drawing, specify a Drawing Note "SAFETY WIRE DRILLED HEAD SCREWS AT FINAL ASSEMBLY PER MS 33540."

22.13.2 THREAD PROJECTION THROUGH LOCKNUTS

The projection of a screw or bolt through a lock nut shall be in accordance with MS 33588, namely:

"Round or chamfered end bolts, studs, or screws must extend at least the full round or chamfer through the nut. Flat end bolts, studs, or screws must extend at least 1/32 inch through the nut, except that for screws and bolts of 48 pitch and greater, a minimum of 1-1/2 threads must be exposed.

The maximum length shall be limited by the nearest larger standard screw length beyond the above minimum requirements."

22.13.3 ADHESIVE FOR LOCKING SETSCREWS AND # 10 AND SMALLER FLAT HEAD SCREWS

Cement #EC-1309, made by Minnesota Mining and Manufacturing Company, St. Paul, Minnesota, or equivalent shall be used.

Procedure

1. Clean surfaces free of oil.
2. Dip threaded end of screw in cement (minimum of 1-1/2 D).
3. Insert screw and tighten.
4. If no adhesive is visible (red color) as a result of tightening, apply a small amount of adhesive to indicate that the part has been locked.
5. Allow four hours to dry.



THREADS AND THREADED FASTENERS

22.14 TORQUE VALUES

Torque values (when required) for #8 through 1- $\frac{1}{4}$ " fine threaded nuts, bolts, and screws may be per ABMA-STD-18 where practical. The torque value shall be specified on the drawing for those sizes not listed in ABMA-STD-18.

Example:



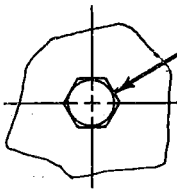
TORQUE PER ABMA-STD-18



TORQUE _ to _ IN-LBS AT ASSEMBLY

3

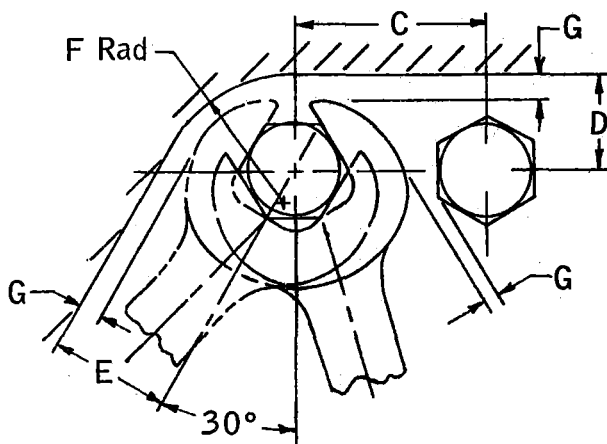
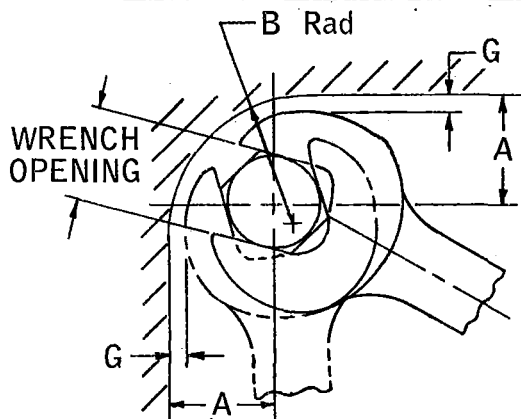
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THREADS AND THREADED FASTENERS

22.15 OPEN-END WRENCH CLEARANCES

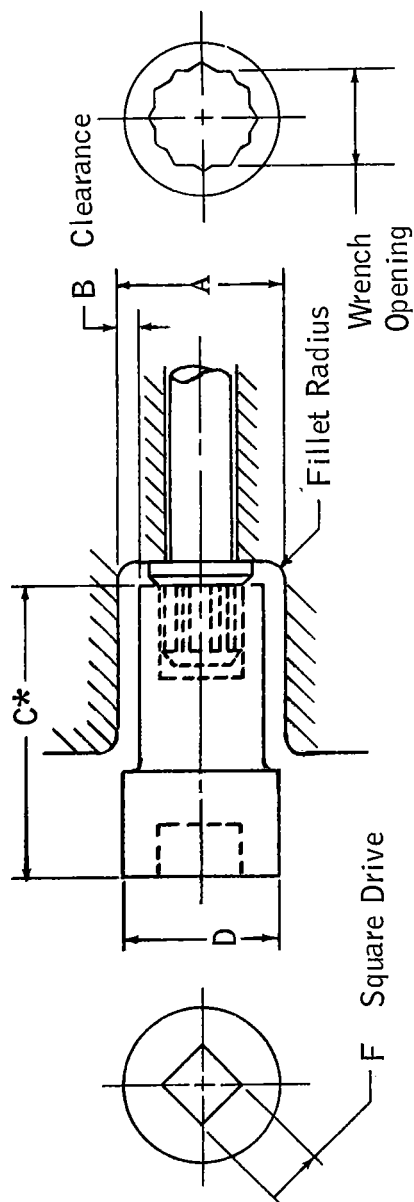


H = Thickness of Wrench Head

Open-End Engineers' Wrench 15°								
Wrench Opening	A Min	B Max	C Min	D Min	E Min	F Max	G Ref	H Max
.156	.220	.250	.390	.160	.250	.200	.030	.094
.188	.250	.280	.430	.190	.270	.230	.030	.172
.250	.280	.340	.530	.270	.310	.310	.030	.172
.312	.380	.470	.660	.280	.390	.390	.050	.203
.344	.420	.500	.750	.340	.450	.450	.050	.203
.375	.420	.500	.780	.360	.450	.520	.050	.219
.438	.470	.590	.890	.420	.520	.640	.050	.250
.500	.520	.640	1.000	.470	.580	.660	.050	.266
.562	.590	.770	1.130	.520	.660	.700	.050	.297
.594	.640	.830	1.210	.530	.700	.700	.050	.344
.625	.640	.830	1.230	.550	.700	.700	.050	.344
.688	.770	.920	1.470	.660	.880	.800	.060	.375
.750	.770	.920	1.510	.670	.880	.800	.060	.375
.781	.830	.950	1.550	.690	.890	.840	.060	.375
.812	.910	1.120	1.660	.720	.970	.860	.060	.406
.875	.970	1.150	1.810	.800	1.060	.910	.060	.438
.938	.970	1.150	1.850	.810	1.060	.950	.060	.438
1.000	1.050	1.230	2.000	.880	1.160	1.060	.060	.500
1.062	1.090	1.250	2.100	.970	1.200	1.200	.080	.500
1.125	1.140	1.370	2.210	1.000	1.270	1.230	.080	.500
1.250	1.270	1.420	2.440	1.080	1.390	1.310	.080	.562
1.312	1.390	1.690	2.630	1.170	1.520	1.340	.080	.562
1.438	1.470	1.720	2.800	1.250	1.590	1.340	.090	.641
1.500	1.470	1.720	2.840	1.270	1.590	1.450	.090	.641
1.625	1.560	1.880	3.100	1.380	1.750	1.560	.090	.641

THREADS AND THREADED FASTENERS

22.16 SOCKET WRENCH SIZES AND CLEARANCES



Socket (Regular Length)													
F Drive			.250		.375		.500		.750				
Wrench opening	A Min	B Ref	C Max	D Max	C Max	D Max	C Max	D Max	C Max	D Max			
.188	.370	.030	1.000	.510									
.250	.470	.030	1.000	.510	1.250	.690							
.312	.550	.030	1.000	.510	1.250	.690							
.344	.580	.030	1.000	.519	1.250	.690							
.375	.620	.030	1.000	.580	1.250	.690	1.500	.880					
.438	.750	.030	1.000	.683	1.250	.880	1.500	.940					
.500	.810	.030	1.000	.692	1.250	.880	1.500	.940					
.562	.870	.030			1.250	.932	1.500	.940					
.594	.920	.030			1.250	.963	1.562	.970					
.625	.950	.030			1.250	.995	1.562	1.000					
.688	1.030	.030			1.250	1.058	1.562	1.065					
.750	1.120	.030			1.250	1.120	1.562	1.130					

* Does not include allowance for torque device.



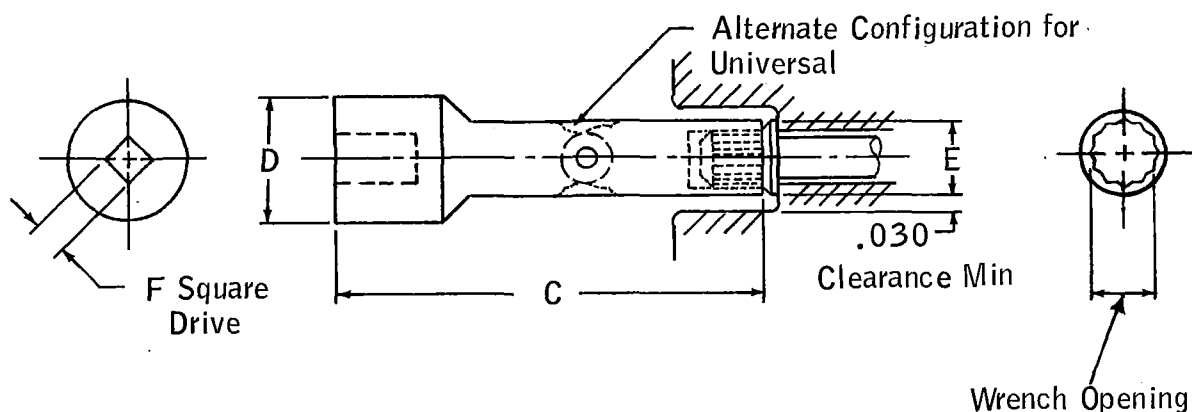
THREADS AND THREADED FASTENERS

22.16 (Contd)

Socket (Regular Length)									
F Drive			.250		.375		.500		.750
Wrench Opening	A Min	B Ref	C Max	D Max	C Max	D Max	C Max	D Max	C Max D Max
.781	1.150	.030			1.250	1.126	1.625	1.130	
.812	1.200	.030			1.250	1.213	1.625	1.222	
.875	1.280	.030					1.750	1.285	
.938	1.370	.030					1.750	1.410	
1.000	1.470	.030					1.750	1.410	
1.062	1.550	.030					1.875	1.505	
1.125	1.610	.030					1.938	1.567	
1.250	1.890	.030					2.000	1.723	2.375 1.855
1.312	1.980	.030							2.500 1.920
1.438	2.140	.030							2.625 2.075
1.500	2.200	.030							2.625 2.170
1.625	2.390	.030							2.750 2.325

THREADS AND THREADED FASTENERS

22.17 THIN-WALL SOCKET WRENCH SIZES AND CLEARANCES



Wrench opening	F	D	E	C	Company	Part No.	Universal
.312	.25	.453	.453	.84	Williams	NM-1210	
	.25	.450	.450	2.00	Williams	NMD-1210	
	.25	*	.422	2.25	Snap-on	TMC-10	
.375	.25	.516	.516	.84	Williams	NM-1212	
	.25	.523	.523	2.00	Williams	NMO-1212	
	.375	.656	.531	1.75	Bonney	LT-12	
.438	.375	.688	.531	1.72	Bonney	TU-12	X
	.25	.609	.609	.84	Williams	NM-1214	
	.25	.603	.603	2.00	Williams	NMD-1214	
.500	.375	.656	.609	2.00	Bonney	LT 14	
	.375	.688	.609	1.72	Bonney	TU 14	X
	.25	.672	.672	.84	Williams	NM-1216	
.562	.375	.688	.688	.91	Bonney	T 16	
	.375	.688	.688	2.00	Bonney	LT 16	
	.375	.688	.688	1.72	Bonney	TU 16	
.625	.25	*	.672	1.75	Snap-on	TMC-16	X
	.375	.781	.781	.91	Bonney	T 18	
	.375	.781	.781	2.00	Bonney	LT 18	
.625	.375	.688	.781	1.75	Bonney	TU 18	
	.375	.844	.812	.94	Bonney	T 20	
	.375	.844	.844	2.25	Bonney	LT 20	
	.375	.688	.644	1.75	Bonney	TU 20	

*Dimensions not available.



 THREADS AND THREADED FASTENERS

22.18 EFFECTIVE THREAD LENGTH

A general rule for maximum effective thread engagement between a screw and tapped hole is:

For Steel, Bronze, and Brass	$1\frac{1}{2} \times \text{Dia Screw Thread}$
For Aluminum Alloys	$2 \times \text{Dia Screw Thread}$
For Magnesium	$2\frac{1}{2} \times \text{Dia Screw Thread}$

The above values are approximate to allow full strength of the material to be utilized when threading directly into the parent metal. The use of inserts, (Helicoil, Rosan, etc.) will effectively shorten these values.

22.19 TAPPING DATA

22.19.1 TAP DRILL DEPTH (BLIND HOLES)

The depth of the tap drill must account for the tapered end of the tap (imperfect threads) plus the accumulation of chips. The chart on the following page shows the minimum distance beyond the required perfect threads that the tap drill must extend.

Blind tapped holes per figure 1a are intended for general-purpose application. They can be produced by a single tapping operation; consequently, this method is normally the most economical.

Blind tapped holes per figure 1b are normally produced in multiple-step threading operation; hence, they are more expensive to produce. These holes should be specified only where smaller depth of hole is required.

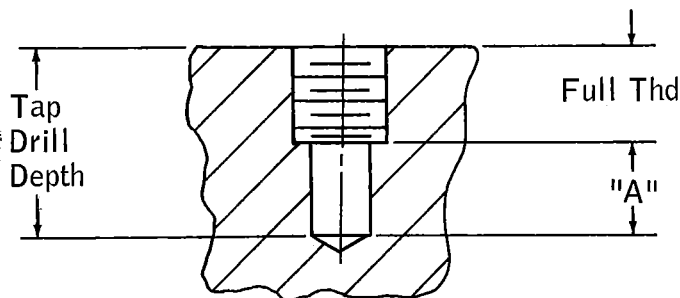


Fig. 1a

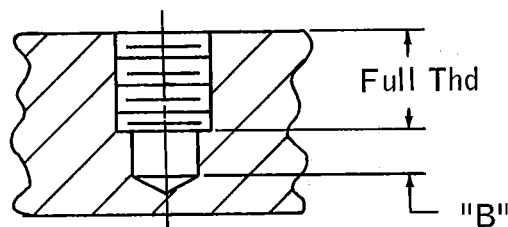


Fig. 1b

THREADS AND THREADED FASTENERS

22.19.1 (Contd)

Size of tap	"A" (Fig. 1a)	Tol	"B" + .02 - .00 (Fig. 1b)
#2	.10	+ .02 - .00	.04
#4	.16	+ .06 - .00	.06
#6	.19	+ .12 - .00	.06
#8	.19		.06
#10	.25		.06
1/4	.32		.10
5/16	.35		.10
3/8	.38		.12
1/2	.47		.14
5/8	.57		.16
3/4	.63		.20
7/8	.69		.20
1	.75		.20

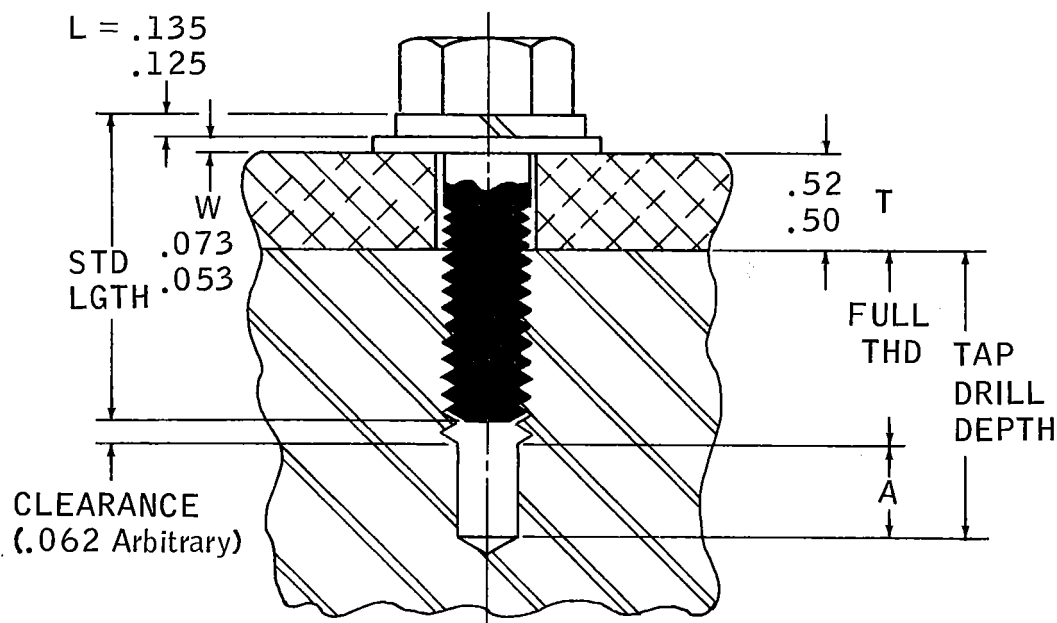
Consideration of the following variables in determining depth of tapped hole may frequently be economical.

- a. Desired minimum engagement of thread.
- b. Thickness and tolerance variations of material under the head of the screw (washer, lockwasher, panel, etc.).
- c. Length and tolerance of standard screw.

THREADS AND THREADED FASTENERS

22.19.1.1 Determination of Depth of Tap

Ex. Problem - Determine tapping requirements for hole for a standard 1/2-13 cap screw having minimum engagement of 1 1/2 x Dia of Thd.



Min Required Engagement = 1.5 x .5	= .750
Max T	= .520
Max W	= .073
Max L	= .135
Min Length of Screw Required	= 1.478
Nearest Standard Length	= 1.500 +.063 -.000

To Determine Max Engagement. Thus, Tapping Requirements:

Max Screw Length	= 1.563
Minus Min T .500	
Min W .053	
Min L .125	
<u>.678</u>	<u>-.678</u>
Max Projection of Screw into Tapped Hole	= .885
.885 + .062 (Clearance) = .947 or .95 Min Full Threads Required	
.95 + .47 (A) = 1.42 Min Tap Drill Depth	

As called on Drawing:

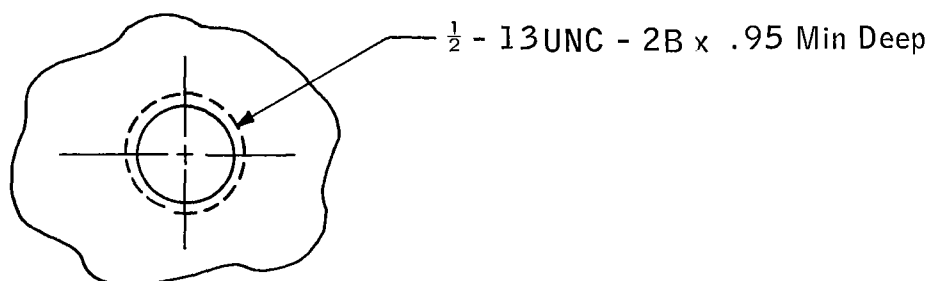
Tap Drill 1.42 - 1.54 Deep & 1/2-13 UNC-2B .95 Min Deep.

THREADS AND THREADED FASTENERS

22.19.1.2 Method of Specifying Tapped Holes

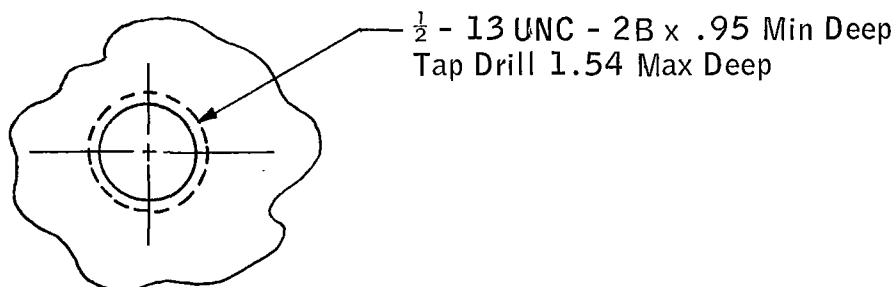
a. In the majority of cases, specification of depth of full thread can be restricted to only the minimum depth required. This, accompanied by the tap drill depth (when the design requires it), completely defines the design requirements and simplifies inspection.

Typical drawing callout:



b. The above example places no restriction on tap drill depth. The manufacturer is required to provide .95 depth of full thread by whatever means he chooses.

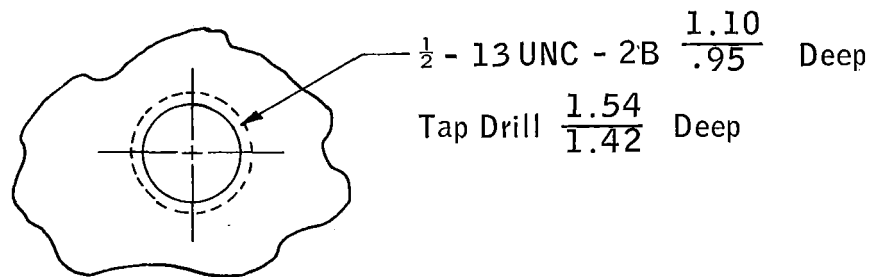
This is the most economical means of calling for tapped holes and shall be utilized whenever possible.



c. The above shall be used where the design requires tap drill depth control.

THREADS AND THREADED FASTENERS

22.19.1.2 (Contd)



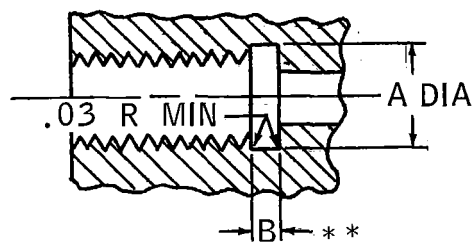
d. The above example should only be used to control thread depth when absolutely necessary. It implies that inspection of both the Max and Min Depth of full threads and tap drill depth is necessary.

22.20 TOOL RELIEF DATA

22.20.1 TOOL RELIEF - INTERNAL THREADS

A third (and more costly) method of producing internal threads for restricting applications is by use of an undercut or tool relief. This method is not recommended for threads under $\frac{1}{2}$ " Dia.

The chart below gives recommended tool relief dimensions and tolerances.



*TOOL RELIEF

THREADS AND THREADED FASTENERS

22.20.1 (Contd)

Thread size	B - Min	A $\begin{smallmatrix} +.02 \\ -.00 \end{smallmatrix}$
1/2 - 20	.10	.52
1/2 - 13	.16	
9/16 - 18	.12	.60
9/16 - 12	.18	
5/8 - 18	.12	.66
5/8 - 11	.18	
3/4 - 16	.14	.78
3/4 - 10	.20	
7/8 - 14	.14	.90
7/8 - 9	.22	
1" - 14	.14	1.04
1" - 8	.26	
1 1/4 - 12	.18	1.28
1 1/4 - 7	.28	
1 1/2 - 12	.18	1.54
1 1/2 - 6	.34	

** A recommended tolerance for dimension "B" is $\begin{smallmatrix} +.02 \\ -.00 \end{smallmatrix}$

* The tool relief shown should be used only when necessity warrants, as they are costly to produce.

22.20.2 TOOL RELIEF - EXTERNAL THREADS

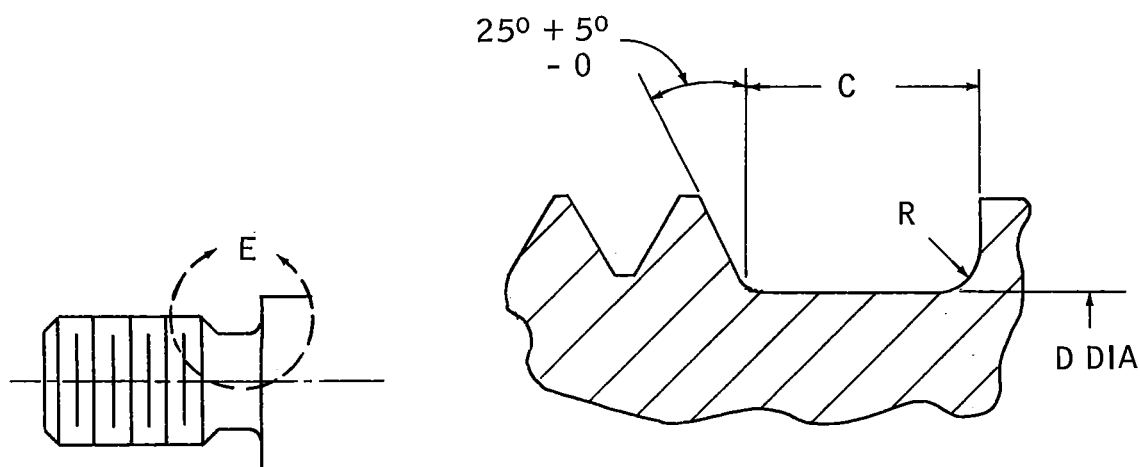
External threads may be machined to within $2\frac{1}{2}$ threads of a shoulder without the necessity of an undercut or tool relief.

When the design requires a thread to continue to the shoulder, an undercut or tool relief, according to the following charts, may be employed.



 THREADS AND THREADED FASTENERS

22.20.3 STANDARD EXTERNAL THREAD UNDERCUTS

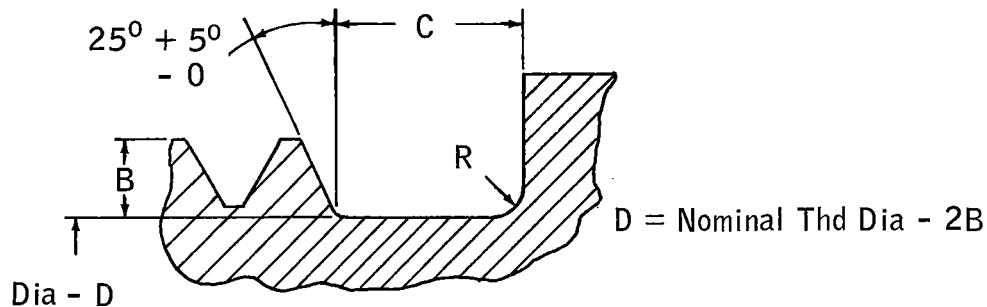
ENLARGED VIEW
"E"

Thread size	Undercut Dia "D"		"C"		Radius "R"	
	Max	Min	Max	Min	Max	Min
8-32	.122	.118	.061	.050	.020	.014
10-32	.148	.144	.061	.050	.020	.014
1/4-20	.182	.176	.093	.080	.050	.040
5/16-18	.236	.230	.110	.090	.050	.040
3/8-16	.291	.281	.125	.100	.062	.050
1/2-13	.396	.386	.140	.120	.062	.050
5/8-11	.501	.491	.170	.140	.078	.060
3/4-10	.614	.600	.188	.160	.078	.060
1-8	.830	.814	.234	.200	.093	.080
1 1/4-8	1.080	1.064	.234	.200	.093	.080
1 1/2-8	1.330	1.314	.234	.200	.093	.080
2-8	1.830	1.814	.234	.200	.093	.080
2 1/2-8	2.330	2.314	.234	.200	.093	.080
3-8	2.830	2.814	.234	.200	.093	.080

THREADS AND THREADED FASTENERS

22.20.4 EXTERNAL THREAD UNDERCUT CALCULATIONS

For the calculation of undercuts of external threads not listed in the preceding table, the following factors shall be used:



Threads per inch	C		R		B	
	Max	Min	Max	Min	Max	Min
4	.484	.390	.188	.170	.186	.170
4½	.438	.350	.156	.140	.166	.151
5	.391	.310	.156	.140	.150	.136
6	.327	.260	.125	.110	.124	.113
7	.281	.220	.110	.100	.107	.098
8	.234	.200	.093	.080	.093	.085
9	.218	.170	.093	.080	.083	.076
10	.188	.160	.078	.060	.075	.068
11	.170	.140	.078	.060	.068	.062
12	.156	.130	.078	.060	.062	.057
13	.141	.120	.062	.050	.057	.052
14	.141	.110	.162	.050	.053	.048
16	.125	.100	.062	.050	.047	.042
18	.110	.090	.050	.040	.041	.038
20	.093	.080	.050	.040	.037	.034
24	.080	.065	.027	.020	.031	.028
28	.069	.056	.023	.017	.026	.024
32	.061	.050	.020	.014	.023	.021
36	.053	.044	.018	.012	.0195	.019
40	.048	.040	.016	.010	.0175	.017

SECTION 22

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KSC



MANUAL

Ground Support Equipment

THREADS AND THREADED FASTENERS

22.21 CHAMFER ON EXTERNAL THREADS

All external threaded ends shall be chamfered in accordance with data given in KSC-STD-168.

22.22 COUNTERSINK DATA (FOR TAPPED HOLES)

All tapped holes shall be countersunk before tapping to prevent burrs in tapping. Through tapped holes shall be countersunk at both ends where practicable. See KSC-STD-168.

REVISED _____

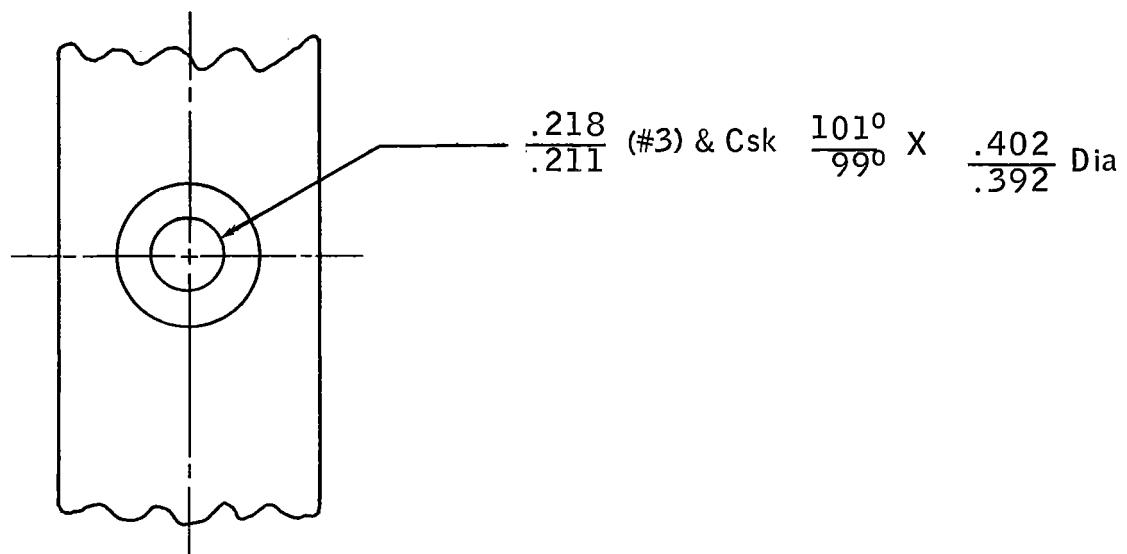
THREADS AND THREADED FASTENERS

22.23 COUNTERSINK DATA (FOR FLAT HEAD SCREWS)

When thickness of material is less than that shown in the following table, the drawing must specify a countersink in mating part to provide clearance for bottom of screw head.

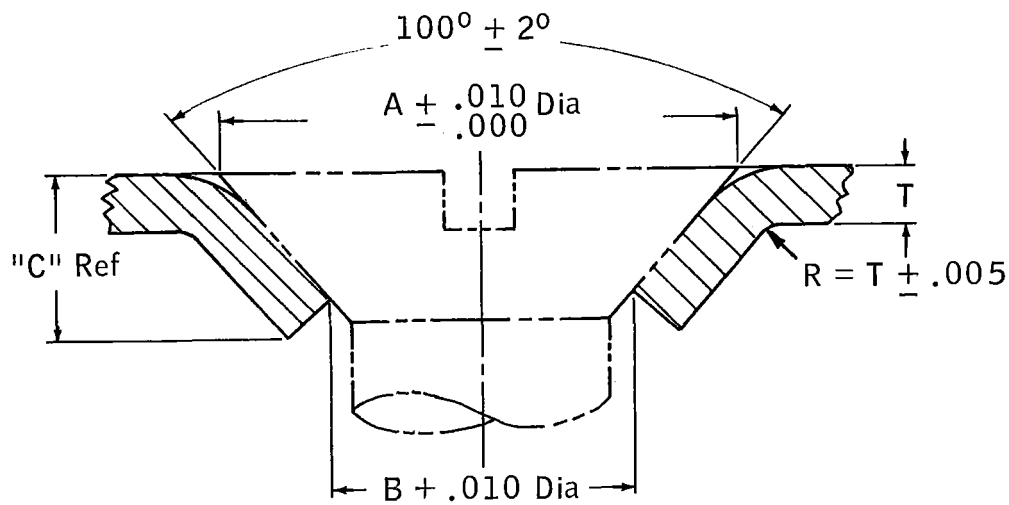
100° Head		
Screw size	Minimum material thickness	Countersink diameter
#4	.064	.229 $\begin{smallmatrix} +.010 \\ -.000 \end{smallmatrix}$
#6	.086	.284
#8	.102	.338
#10	.109	.392
1/4	.138	.516
5/16	.187	.647
3/8	.203	.775 $\begin{smallmatrix} +.010 \\ -.000 \end{smallmatrix}$

- a. Typical method of specifying drill and countersink on drawing for flat head screws.





 THREADS AND THREADED FASTENERS

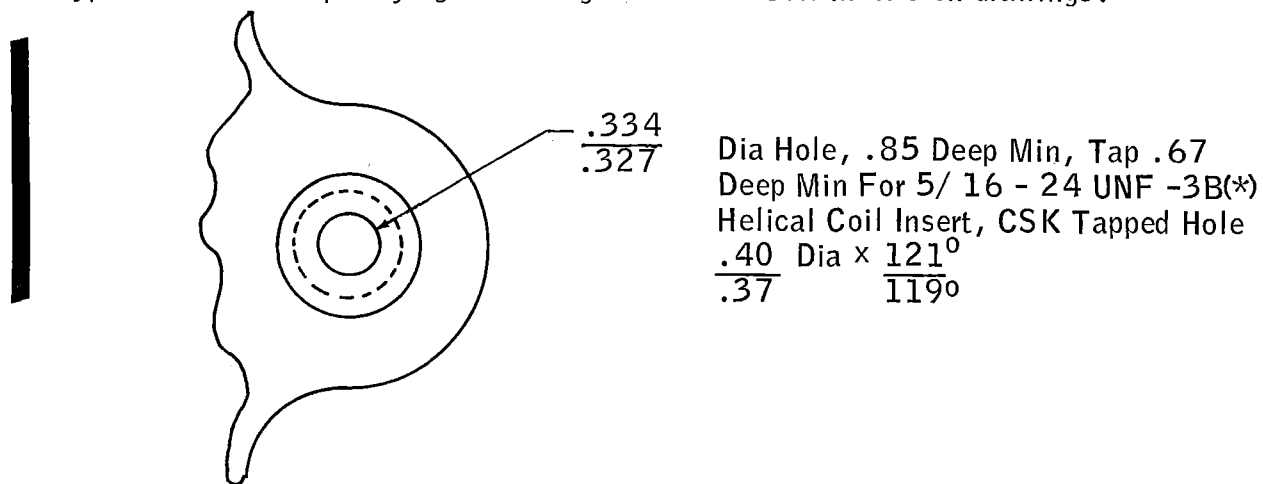
22.24 DIMPLING (FOR FLAT HEAD SCREWS)

Screw size	A	B	"C" for Thickness of Matl. Shown				
			.031	.040	.063	.090	.125
#6	.279	.170	.068	.076	.093	.114	.141
#8	.332	.196	.081	.088	.105	.126	.153
#10	.385	.221	.093	.100	.117	.138	.165
1/4	.507	9/32	.119	.126	.143	.164	.191
5/16	.635	23/64	.140	.147	.164	.185	.212
3/8	.762	27/64	.167	.174	.191	.212	.239

THREADS AND THREADED FASTENERS

22.25 THREADED INSERTS

Typical method of specifying machining for Helical Coil Inserts on drawings.



Helical Coil Inserts shall be specified by the MS number (when available).

See Section 9 for applicable drawing notes.

*For Screwlock Inserts, specify class 2B for screw sizes up to size No. 8 and class 3B for screw sizes No. 10 and larger. For Standard-Type Inserts specify class 2B for all sizes.

RIVETING

23.1 RIVET SYMBOLS

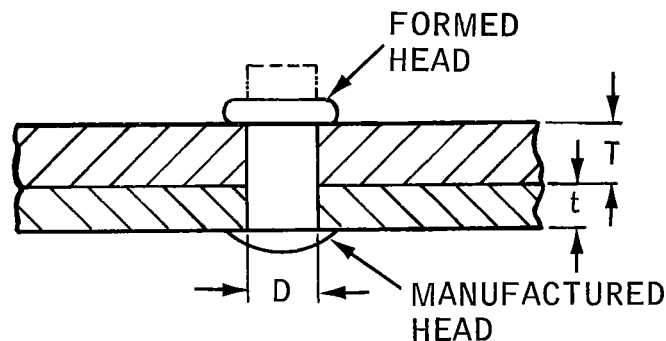
NAS 523 provides a method for simplified rivet callouts. The symbol consists of a single cross; the intersection of the cross is at the location of the fastener. Coding is within the symbol by quadrants. This system may be used where applicable, providing that all rivets are called for on the Parts List of the drawing and the part numbers are identified with their respective symbol.

23.2 DESIGN DATA

23.2.1 SELECTION OF RIVET DIAMETER

The following factors should be considered when designing parts to be riveted:

- a. As a general rule in riveting sheet metal, the diameter "D" of the rivet should not be smaller than the thickest sheet (T) nor larger than three times the thinnest sheet (t).

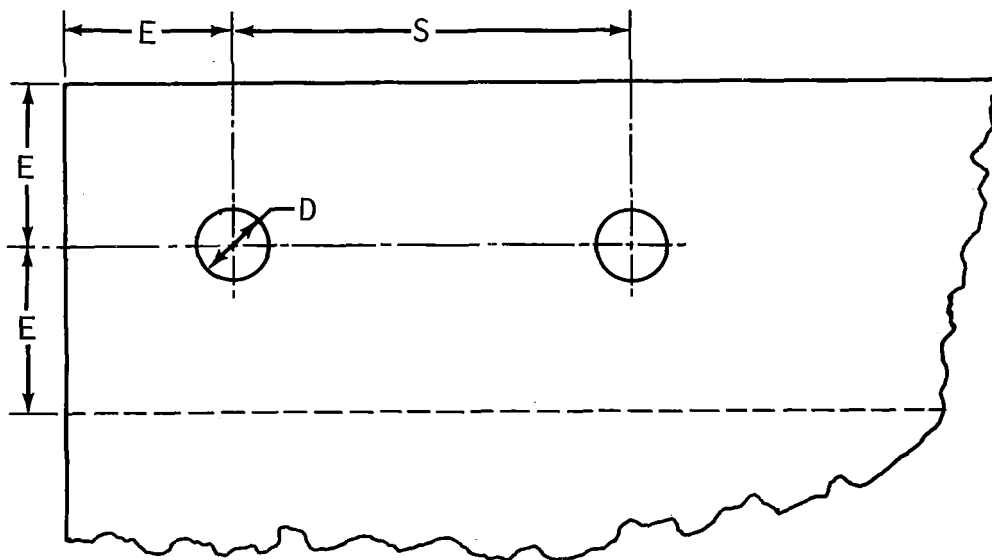


$$D \geq T \text{ and } D \leq 3t$$

- b. Recommended practice is to place the manufactured head against the thinner material when riveting two different thicknesses or against the softer material when using soft and hard material combinations.
- c. When the rivet must be upset against a material softer than the rivet material, a washer shall be specified under the upset head.

RIVETING

23.2.2 SPACING AND EDGE DISTANCE

23.2.2.1 General Application

For noncountersunk hds

$$\text{Min } E = 2D$$

$$\text{Min } S = 4D$$

For countersunk hds up to .50 D

$$\text{Min } E = 2D + .06$$

$$\text{Min } S = 4D$$

23.2.2.2 Specific Application

For castings

$$\text{Min } E = 3D$$

$$\text{Min } S = 4D$$

For plywood

$$\text{Min } E = 4D$$

$$\text{Min } S = 4D$$

For molded (plastics)

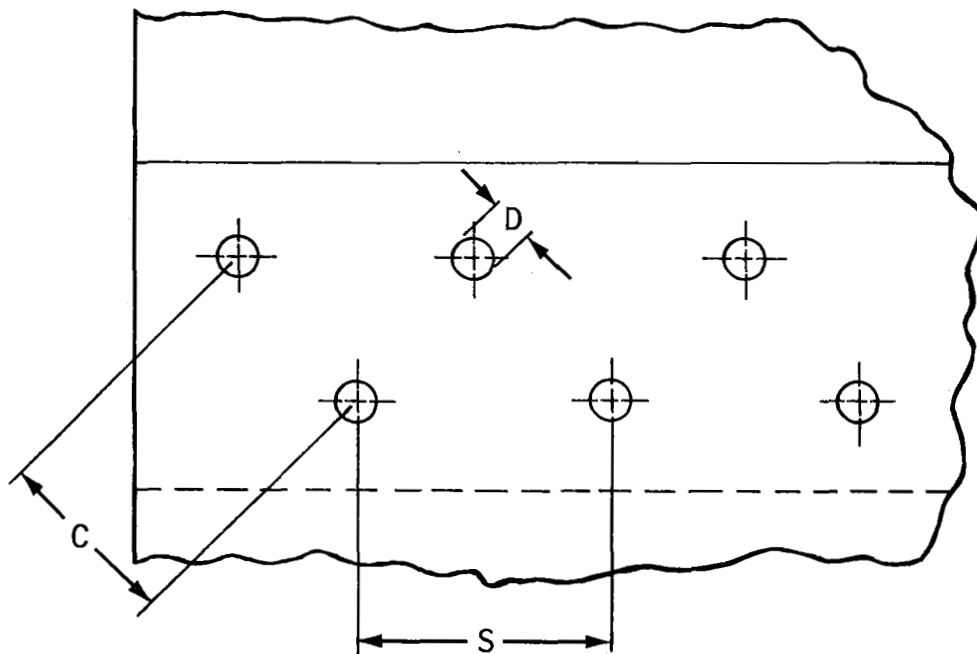
$$\text{Min } E = 3D$$

$$\text{Min } S = 4D$$

RIVETING

23.2.2.3 Multiple Rows

Multiple rows of rivets should be employed where the effect of closer spacing is desired.



$$\text{Min } C = 3D \quad \text{Min } S = 4D$$

Edge distance $2D$ Min



RIVETING

23.2.3 MATERIALS AND APPLICATION

RIVETS			
KIND OF RIVET	TEMPER AFTER DRIVING	HEADS AVAILABLE	APPLICATION
2117-T4 (Type AD)	2117-T3 (driven at room temp)	Universal MS20470 & 100 ⁰ flush MS20426	All standard splices of aluminum alloy and where possible, in combinations of aluminum and corrosion resistant steel.
2024-T4 (Type DD)	2024-T31 (driven from ice box in AQ)	Universal MS20470 & 100 ⁰ flush MS20426	Where higher rivet strength is mandatory.
1100-F (Type A)		Universal MS20470 & 100 ⁰ flush MS20426	Low strength; non-structural applications.
Monel (Type M) (Specify annealed condition)		Round MS20615 & 100 ⁰ flush MS20427	For joining corrosion resistant steel, CP titanium, inconel, etc. Expensive and hard to drive. AD rivets or spot welding should be specified wherever possible.
5056-H32 (Type B)	5056-H321	Universal MS20470 & 100 ⁰ flush MS20426	All joints containing magnesium, plywood, or micarta.
Aluminum Alloy		Oval MS16535	Use only for fabric, leather, plywood, etc. for nonstructural attachments.
Mild Steel		CSK MS 16536	
Copper		CSK MS 16536	

RIVETING

23.2.4 COUNTERSINKING

Countersinking shall generally be used in preference to dimpling. However, there are minimum material thicknesses below which countersinking cannot be used; in such cases, holes must be dimpled. It is necessary for rivet callouts to specify countersinking or dimpling as required. The minimum thicknesses for countersinking are shown in Table 23-1.

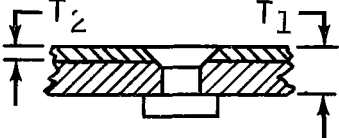
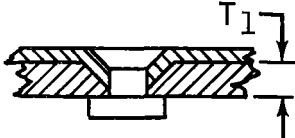
NOTE: Sheets thick enough for countersinking may be dimpled if they are within the limits set forth in Table 23-1.

Table 23-1. Minimum Thickness for Countersinking

Rivet Size	3/32	1/8	5/32	3/16	1/4	5/16	3/8
Minimum Allowance T_1	.040	.051	.064	.081	.125	.125	.156
Minimum Allowance T_2	.032	.040	.040	.040	.040	.040	.040

T_1 = Total thickness of sheet countersunk.

T_2 = Thickness of top sheet held in place by flush rivet.

23.2.5 SPOTFACE DIAMETERS

The values given in the table below provide adequate clearance for standard Universal head rivet sets.

MS20470 Rivet Size	Minimum Spotface Diameters
3/32	3/8
1/8	7/16
5/32	1/2
3/16	9/16
1/4	11/16

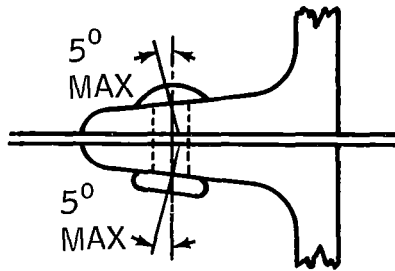
RIVETING

23.2.6 COCKED RIVET HEADS

- a. Maximum permissible cocking of either head of a standard rivet is 5° .

NOTE: Rivets can be driven at greater angles with special care.

- b. The bearing area under the head should be spotfaced if the angle would otherwise exceed 5° .



23.2.7 BLIND RIVETS

In general, blind rivets should be avoided in design; however, they may be called for in applications where inaccessibility precludes the use of solid rivets. They may not be used in applications where the failure of a few rivets would seriously impair the safety of the item. MS33522 should be consulted for design limitations.

23.2.8 UNSUPPORTED RIVET SHANK

Rivets with unsupported shanks shall be avoided in design. Any application of such rivets must have the approval of design supervision.

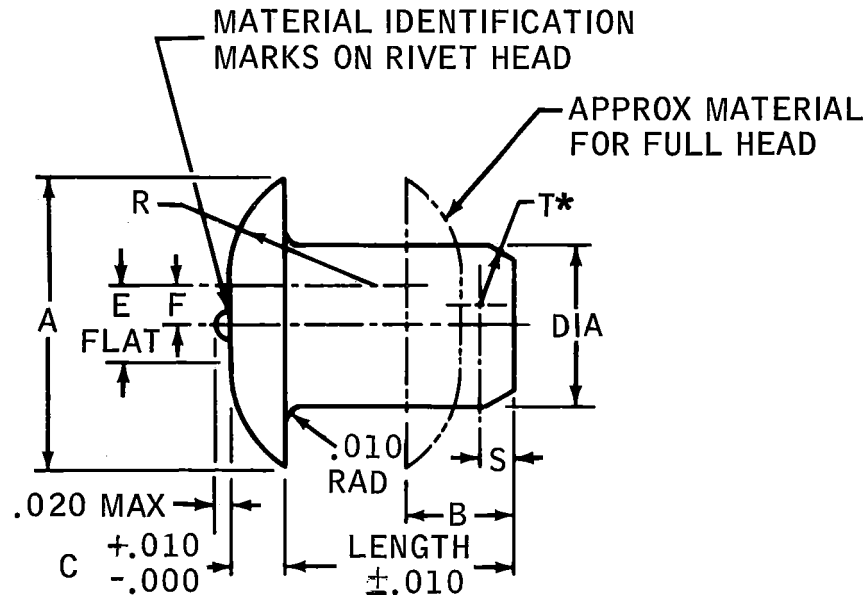
23.2.9 DIMPLING

For information on dimpling, consult MSFC-STD-156.

RIVETING

23.2.10 RIVET DATA FOR REFERENCE

23.2.10.1 Solid Rivet - Universal Head - MS20470

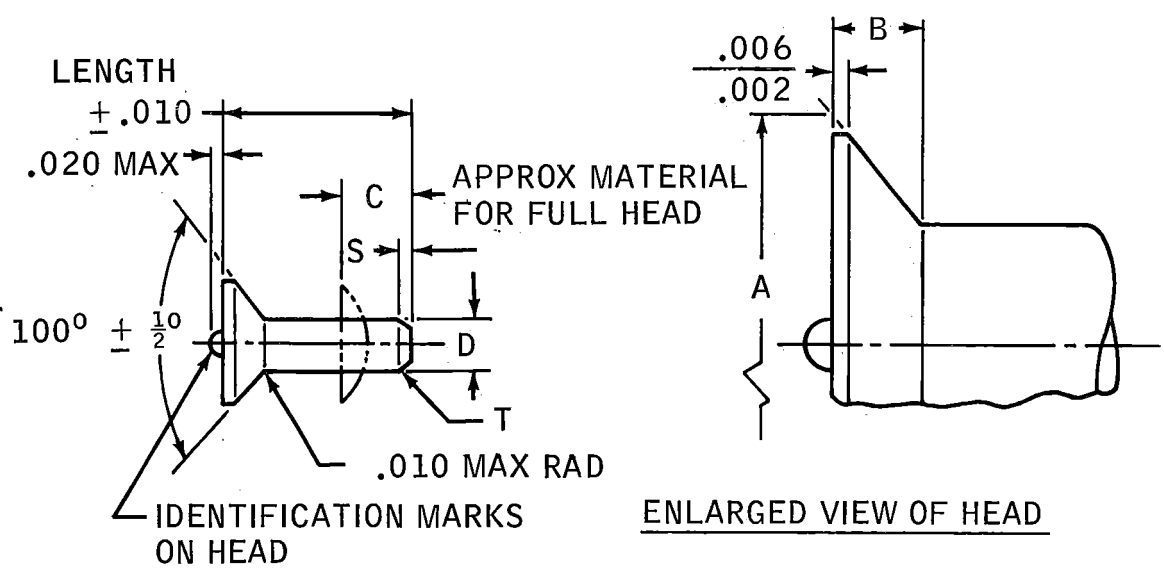


NOM DIA	DIAMETER		A	B	C	E	F	R	S	T RAD
1/16	.062	± 0.003 -0.001	.125 ± 0.006	.094	.027	.031	.015	.054	.016	.019
3/32	.094		.187 ± 0.009	.141	.040	.046	.023	.082	.023	.029
1/8	.125		.250 ± 0.012	.188	.054	.062	.031	.108	.031	.039
5/32	.156	± 0.004 -0.001	.312 ± 0.016	.234	.067	.078	.039	.135	.039	.049
3/16	.187		.375 ± 0.019	.281	.080	.093	.046	.164	.047	.059
7/32	.219		.437 ± 0.022	.328	.093	.109	.054	.193	.054	.069
1/4	.250		.500 ± 0.025	.375	.107	.125	.062	.217	.062	.078
5/16	.312		.625 ± 0.031	.469	.133	.156	.078	.272	.078	.098
3/8	.375		.750 ± 0.037	.562	.161	.187	.093	.328	.094	.117

*Rivets may be furnished with plain ends, or chamfered ends with a radius to the T dimension, or a 20° chamfer to the S dimension.

RIVETING

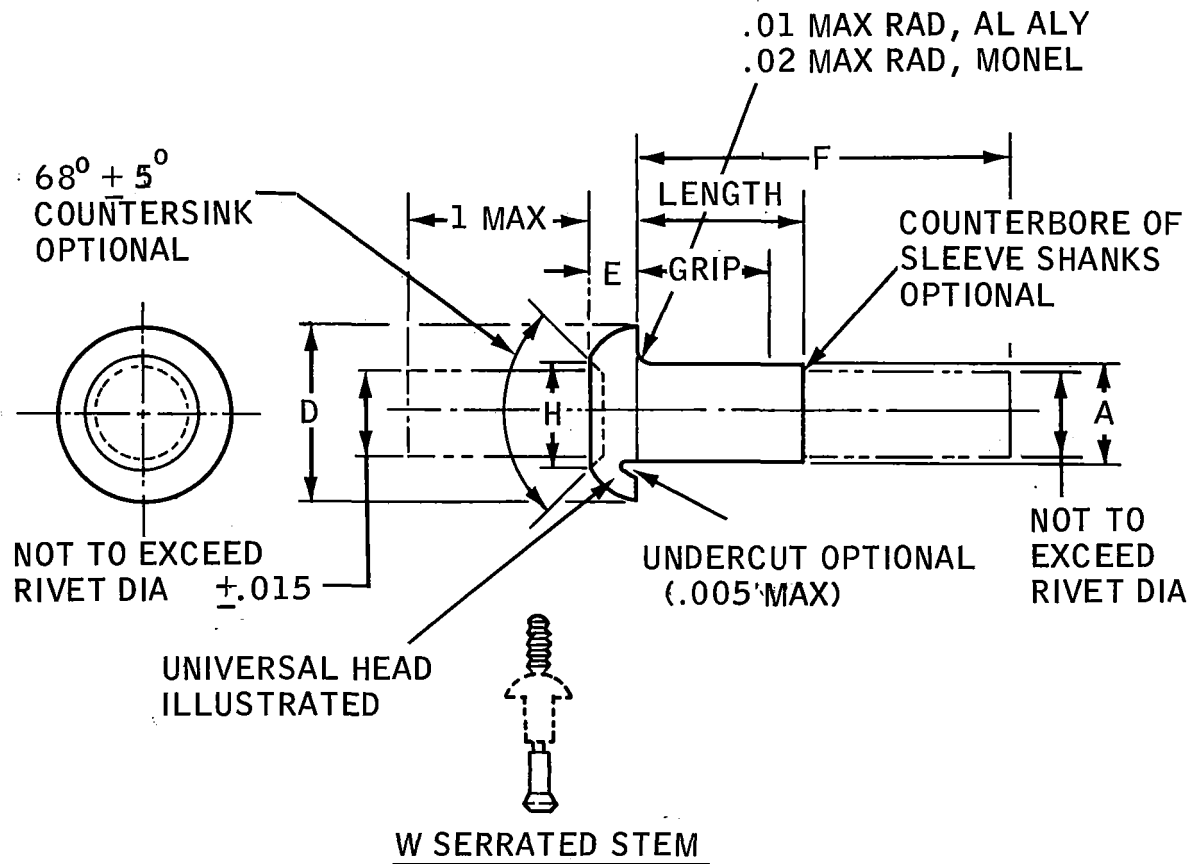
23.2.10.2 Solid Rivet- Countersunk Head - MS20426



D +.003 -.001 DIA	A $\pm .004$ DIA	B REF	C	S	T RAD
.062	.114	.022	.094	.016	.019
.094	.179	.036	.141	.023	.029
.125	.225	.042	.188	.031	.039
.156	.286	.055	.234	.039	.049
.187	.353	.070	.281	.047	.059
.219	.415	.083	.328	.054	.069
.250	.476	.095	.375	.062	.078
.312	.564	.106	.469	.078	.098
.375	.694	.134	.562	.094	.117

RIVETING

23.2.10.3 Rivet Blind, Self Plugging - MS20600



RIVET SIZE NOM DIA	A +.003 -.001 DIA	UNIVERSAL HEAD		H MAX
		D DIA	E +.010 -.000	
1/8	.125	.250 ±.012	.054	.110
5/32	.156	.312 ±.016	.067	.138
3/16	.187	.375 ±.019	.080	.161
1/4	.250	.500 ±.025	.107	.215

RIVETING

NOT TO EXCEED
RIVET DIA + .015

1 MAX

LENGTH

GRIP

F

COUNTERBORE OF
SLEEVE

SHANKS OPTIONAL

68° + 5°
COUNTERSINK
OPTIONAL

100° + 1°
± 1-1/2° (MONEL)

.01 MAX RAD, AL ALY
.02 MAX RAD, MONEL

NOT TO EXCEED
RIVET DIA

.022 - .006 (AL ALY)
.005 - .015 (MONEL)

C
(REF)

B

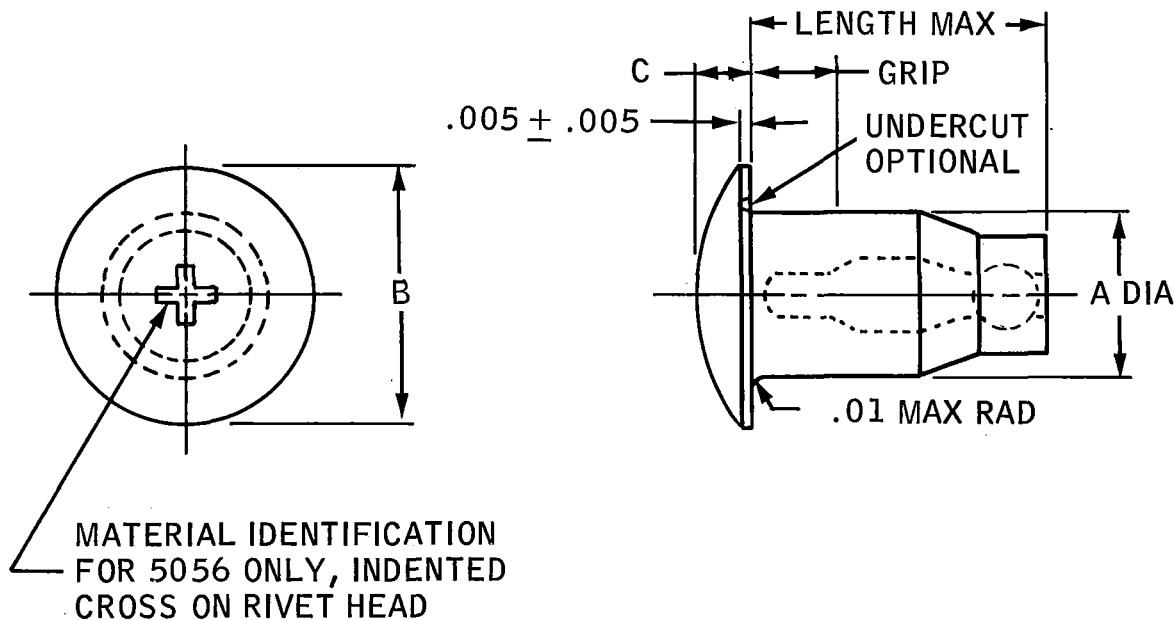
W SERRATED STEM

ENLARGED VIEW OF HEAD

RIVET SIZE NOM DIA	A +.003 -.001 DIA	B ±.004 DIA	C REF	H MAX
1/8	.125	.225	.042	.110
5/32	.156	.286	.055	.138
3/16	.187	.353	.070	.161
1/4	.250	.476	.095	.215

RIVETING

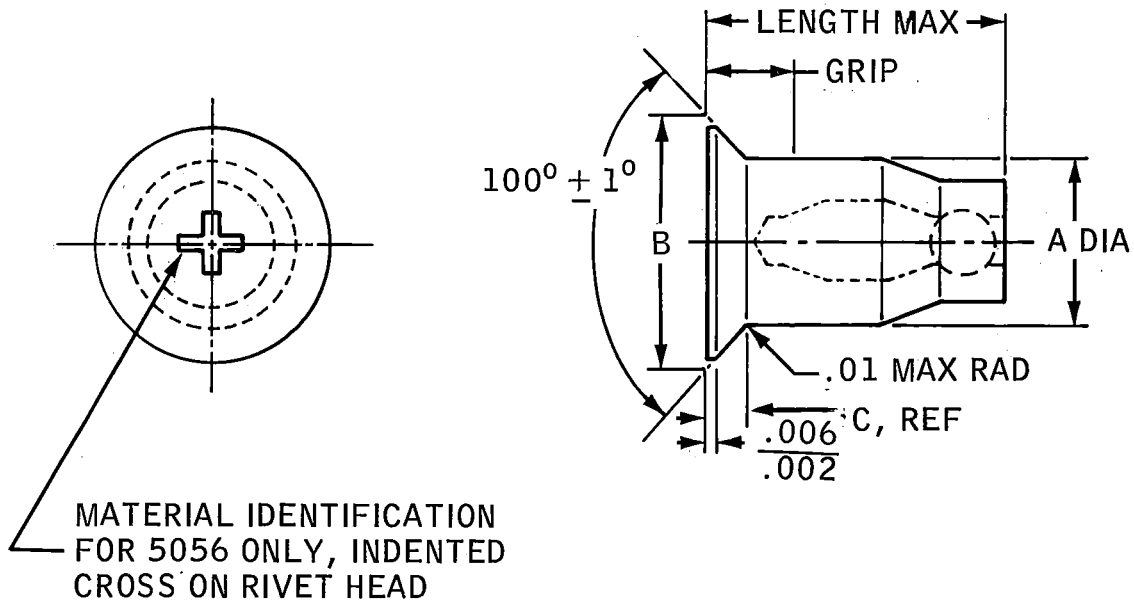
23.2.10.5 Rivet Blind, Chemically Expanded - MS20602



STYLE A CHEMICALLY EXPANDED, CLOSED END RIVETS

RIVET SIZE NOM DIA	A $\pm .001$ DIA	B $\pm .010$	C
1/8	.134	.250	.050 $\pm .003$
5/32	.171	.312	.063 $\pm .004$
3/16	.202	.375	.075 $\pm .005$

RIVETING

23.2.10.6 Rivet Blind, Chemically Expanded, Flush Head - MS20603

STYLE A CHEMICALLY EXPANDED, CLOSED END RIVETS

RIVET SIZE NOM DIA	A $\pm .001$ DIA	B $\pm .004$	C
1/8	.134	.225	.039
5/32	.171	.286	.049
3/16	.202	.353	.064

RIVETING

23.3 DRAFTING PRACTICE

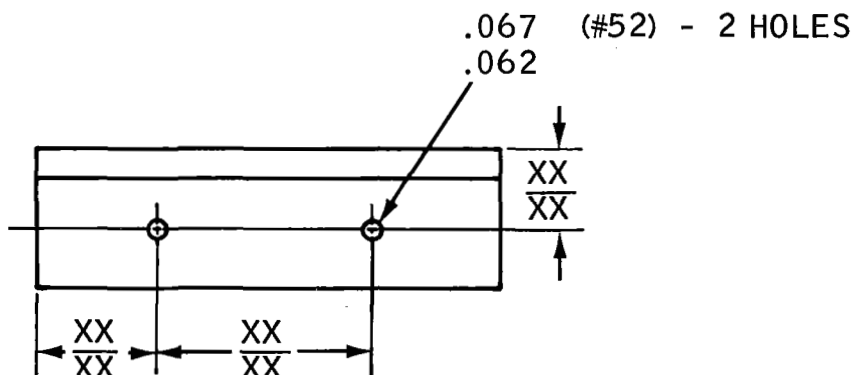
23.3.1 METHOD OF SPECIFYING ON DRAWINGS

When joining two or more parts by riveting, careful consideration must be exercised in determining the method of drilling to be specified in order to guarantee hole alignment for assembling. There are three methods in general use for accomplishing this end result:

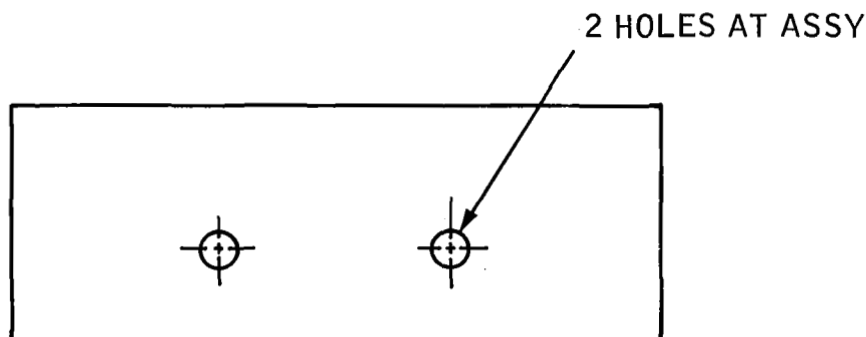
- a. Locate and specify the size of pilot drill and number of rivet holes to be drilled at assembly in the outer or smaller piece. At assembly, locate this piece on its mating part and drill through. The predrilled part thus serves as a drill-template, ensuring alignment. This method shall be employed for general use.

EXAMPLE:

DETAIL

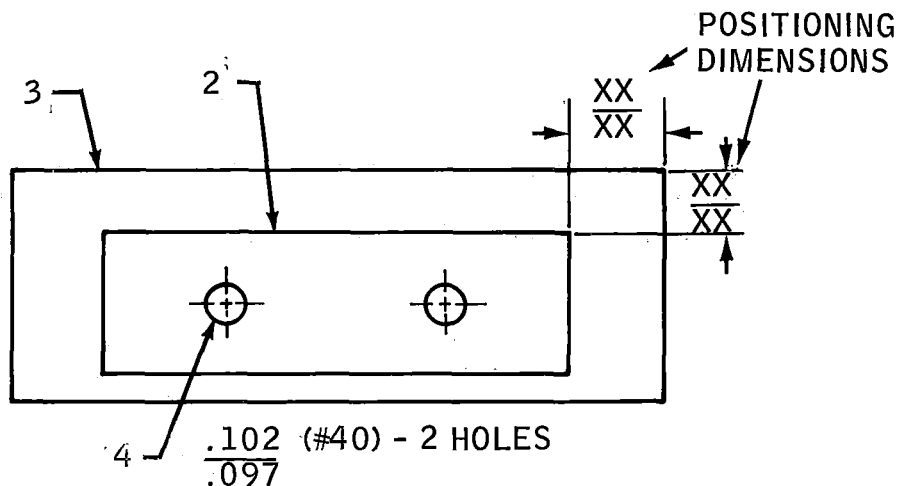


DETAIL



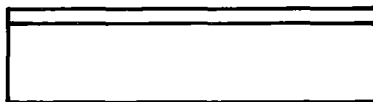
RIVETING

ASSEMBLY
(P4 IS RIVET)

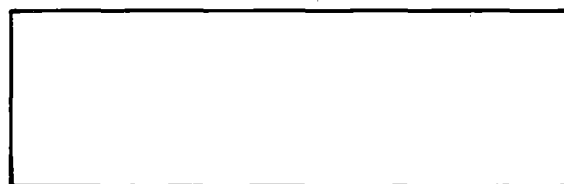


- b. Locate and specify all rivet holes on a riveted assembly drawing. As this method throws an added burden on the shop, it is rarely used except for development or a "one-shot" job.

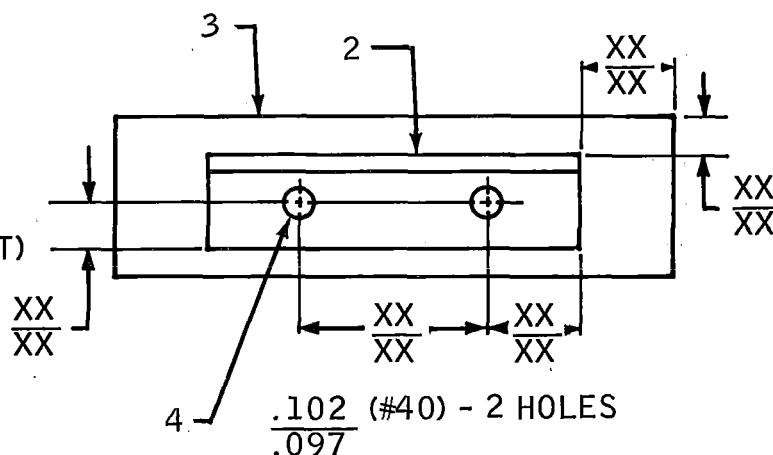
DETAIL



DETAIL



ASSEMBLY
(P4 IS RIVET)



RIVETING

23.3.1 (Contd)

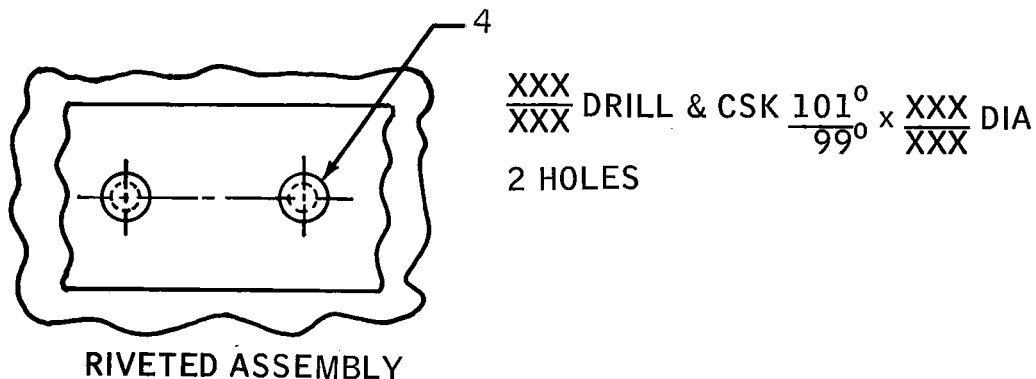
- c. Locate and specify all rivet holes on each detail part with the mandatory close tolerances which are necessary to assure hole alignment at assembly. This method demands more vigilance on the part of drafting plus the additional cost of accurate drill jigs or piercing dies. This is the accepted practice in mass production where the volume of parts produced justifies the additional tool cost.

23.3.2 PILOT HOLE SIZE

Pilot drills shall be used to locate for final drilling to correct size on a later assembly.

<u>RIVET SIZE</u>	<u>PILOT HOLE</u>
.094 DIA	.067 (#52) .062
.125 DIA And Larger	.103 (#40) .098

23.3.3 METHOD OF SPECIFYING DRILLING FOR COUNTERSUNK HEAD RIVETS



23.3.4 DIMENSIONING RIVET SPACING

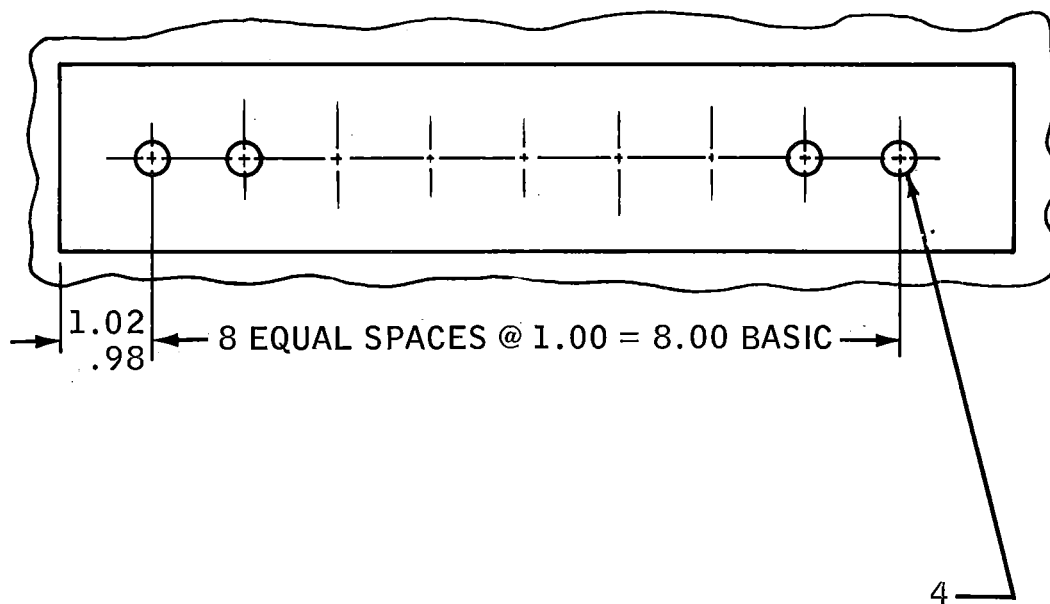
- a. Completely dimension all rivet spacing when individual rivet location is critical.
- b. Always locate end rivets in a run by dimensions which tie into physical features of parts or end rivets of adjacent rivet runs.

RIVETING

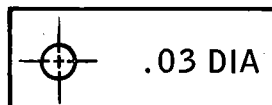
23.3.4 (Contd)

NOTE: A rivet run is defined as a continuous and uniform pattern of rivets uninterrupted by traversing members from which rivet location is critical enough to require dimensioning.

- c. For indeterminate runs, the spacing may be controlled by locating end rivets and specifying the number of equal spaces between them.

EXAMPLE

.102
.097 (#40) - 9 HOLES



RIVETING

23.3.5 DRAWING NOTES

The following notes may be used where applicable:

- 1 - RIVET PER * _____
- 2 - RIVET CODING PER NAS523

*Applicable Spec. No.
MSFC-STD-156
A10509301
OR OTHER

MATERIALS

24.1 GENERAL

Material shall be called for on engineering drawings in accordance with the nomenclature pattern established by the pertinent specification. The chemical composition, physical or electrical properties, or identifying characteristics such as type, grade, class, etc. shall also be specified. Heat treatment or condition of material shall be indicated, when applicable, as part of the material callout. This information shall be placed on drawings and associated lists in accordance with Section 4 of this manual.

In the interest of standardization, the materials listed in this section represent those recommended for general use. Other materials not listed may be used when approved by the responsible design activity. The descriptions of the specifications listed are of a general nature. For detailed requirements such as physical properties, chemical composition, etc. the material specification will have to be consulted.

24.1.1 GALVANIC CORROSION

Whenever two uninsulated dissimilar metals are together in the presence of an electrolyte such as water, the combination creates a galvanic cell and the metal having the higher galvanic potential will corrode. The most efficient manner of corrosion prevention is in the initial production of materials, although protective coatings are used as indicated below. Use metals of the same galvanic group when possible; otherwise, use metals in groups as near to each other as strength and functional requirements permit.

In the following table, metals are grouped as to galvanic similarity and are in agreement with MS33586.

GROUP I (Highest Potential)	GROUP II	GROUP III	GROUP IV (Lowest Potential)
Magnesium Alloys	Aluminum Alloys Cadmium Zinc	Iron Iron Alloys Lead Lead Alloys Tin Tin Alloys Steels (Except Corrosion Resistant Steels)	Chromium Copper Gold Silver Platinum Nickel Titanium Cobalt Rhodium Corrosion Resistant Steels Graphite
			} and their alloys

The Corrosion Control and Treatment Manual, KSC TM-584, may be used as an aid in designing equipment that will be subjected to a corrosive environment.

Some basic rules for reduction of corrosion are:

- Provide drainage holes to prevent accumulation of water.
- Avoid residual stresses in parts.
- Provide surface coatings, paint, plating, or other protection.

MATERIALS

24.1.2 MATERIAL SPECIFICATIONS

In general the material specifications listed in this section are military and federal specifications. Commercial specifications exist in many cases which are chemically equivalent and should be considered in the interest of possible cost savings. Available references such as Military Handbooks and Materials Reference Manual for Mechanical Launch Support Equipment, Launch Complex 39, KSC TM-593, may be consulted when selecting materials.

24.2 METALLIC MATERIALS**24.2.1 ALUMINUM AND ALUMINUM ALLOYS** (Reference: MIL-HDBK-694 Military Standardization Handbook, Aluminum and Aluminum Alloys)

Wrought aluminum and wrought aluminum alloys are designated by a four-digit index system. The first digit of the designation serves to indicate the alloy group, as shown below. The second digit indicates modifications of the original alloy; zero designates the original alloy, and 1 through 9 are assigned consecutively to its modifications.

DESIGNATIONS FOR ALLOY GROUPS

Aluminum - 99.00% Minimum and Greater.		1xxx
Major Alloying Element		
Aluminum	Copper	2xxx
Alloys	Manganese	3xxx
Grouped	Silicon	4xxx
By Major	Magnesium	5xxx
Alloying	Magnesium and Silicon	6xxx
Elements	Zinc	7xxx
	Other Element	8xxx
Unused Series		9xxx

The temper designations follow the alloy designations and are separated from them by a dash; e.g., 3003-H16 or 2024-T6.

Heat-treatable aluminum alloys are those which can be hardened by thermal treatment. It is desirable, when other than simple forming is required, to fabricate in the annealed temper since much greater formability is available, and high-residual forming stresses are erased by subsequent heat treatment. Similarly, maximum weld strength is obtainable only if the part is welded prior to heat treatment. Fusion welding after heat treatment always produces a partial anneal and impairs the corrosion resistance of these alloys.

Resistance welding may be used after heat treatment as it can be controlled to reduce the annealing effect.

Best machinability is in the heat treated and fully aged tempers. (Non-heat treatable alloys machine best in full hard tempers.)

MATERIALS

24.2.1.1 Bar, Rod, Shapes and Tube, Extruded. QQ-A-200 Series

- | | |
|-----------------------|---|
| QQ-A-200/2
2014-* | For high-strength structural extrusions. Welding is restricted.
*Specify T4 or T6. |
| QQ-A-200/8
6061-* | Good corrosion resistance and good formability. May be fusion welded in all tempers; may be resistance welded. Has good strength.
*Specify T4 or T6. |
| QQ-A-200/9
6063-* | For use where good corrosion resistance is required. Limited machineability. May be both fusion and resistance welded.
*Specify T4 or T6. |
| QQ-A-200/11
7075-* | Highest strength aluminum alloy. May be resistance welded.
*Specify T6. |

24.2.1.2 Bar, Rod, Wire, and Special Shapes, Rolled, Drawn, or Cold-Finished. QQ-A-225 Series

- | | |
|----------------------|---|
| QQ-A-225/4
2014-* | For use where high strength is required, no welding involved and where optimum corrosion resistance is not required. *Specify T4 or T6. |
| QQ-A-225/6
2024-* | For general structural use. Not to be fusion welded. *Specify T4 or T6. |
| QQ-A-225/8
6061-* | Good corrosion resistance and good formability. May be fusion welded in all tempers; may be resistance welded. *Specify T4 or T6. |
| QQ-A-225/9
7075-* | Highest strength aluminum alloy. Cannot be fusion welded; may be resistance welded. *Specify T6. |

24.2.1.3 Sheet and Plate. QQ-A-250 Series

- | | |
|-------------------------------|--|
| QQ-A-250/4
2024-* | Customarily used only as plate stock. Has high strength. Not to be fusion welded. *Specify T4 or T6. |
| QQ-A-250/5
2024-
ALCLAD | For use where high strength and good corrosion resistance are required. Cannot be fusion welded; may be resistance welded.
*Specify T4 or T6. |
| QQ-A-250/11
6061-* | For use where good strength and good formability are required. Better resistance to corrosion under abrasive conditions than Alclad 2024. Can be fusion and resistance welded.
*Specify T4 or T6. |

MATERIALS

24.2.1.3 (Contd)

QQ-A-250/13 For use wherever high mechanical properties can effect a weight
7075-* savings. Cannot be fusion welded. Good resistance to corrosion.
ALCLAD *Specify T6.

24.2.1.4 Tube. WW-T-700 Series

WW-T-700/2 For parts to be spun, conduit, and similar parts. For use where
3003-* moderate strength, good formability, and weldability are required.
Not heat-treatable. *Specify O, H14, H16, or H18.

WW-T-700/3 For general structural use. Not to be fusion welded. Do not use
2024-* for fluid lines carrying pressure. *Specify T3 or T4.

WW-T-700/4 Intended for use where good workability, resistance to corrosion,
5052-* high fatigue strength, and moderate static strength are desired.
*Specify H32, H34, H36, or H38.

WW-T-700/6 Intended for use when good strength and workability are required.
6061-* *Specify T4 or T6.

24.2.1.5 Pipe, Drawn or Extruded. MIL-P-25995 Series

MIL-P-25995 Intended for use where moderate strength is required.
3003-* *Specify H18 or H112.

MIL-P-25995 Intended for use where good strength, good formability, good corrosion
6061-T6 resistance, and good weldability are required.

24.2.1.6 Forgings, Heat-Treated. QQ-A-367 Series

QQ-A-367 General use, has high strength. *Specify T4 or T6.
2014-*

QQ-A-367 Highest strength aluminum alloy, used for small forgings where
7075-T6 weight saving is essential. Cannot be fusion welded.

24.2.1.7 Structural Shapes, Angles, Channels, I and Z Beams, Extruded or Rolled

MIL-A-25994 Intended for use where moderate to good strength is required, primarily
2014-* applicable to ground-handling equipment and ground-structural use.
6061-* *Specify T4 or T6.
6066-*

MATERIALS

24.2.1.8 Sand Castings. QQ-A-601 Series

- | | |
|------------------------|---|
| QQ-A-601
43F | Excellent casting properties, used for general-type castings for marine fittings. Has good corrosion resistance and is non-heat-treatable. |
| QQ-A-601
356-* | Excellent casting properties, used for general-type castings for aircraft fittings and pump bodies. Has high resistance to corrosion and is heat-treatable. *Specify T4, T6 or T51. |
| QQ-A-601
355-* | General use, has high strength and resistance to corrosion. Good machinability and is heat-treatable. *Specify T6, T51, T7, or T71. |
| QQ-A-601
ALMAG 35-* | Good casting properties, shock and corrosion resistant, excellent machinability. *Specify F or T4. |

24.2.2 COPPER, BRASS, AND BRONZE (Reference: MIL-HDBK-698 (MR) Military Standardization Handbook, Copper and Copper Alloys)

24.2.2.1 Tube

- | | |
|--------------------|---|
| WW-T-791
BRASS | Seamless, for unstressed parts to be soldered or threaded. Lighting fixtures, tank fittings, etc. |
| WW-T-799
COPPER | Seamless, for use with soldered or flared fittings. |

24.2.2.2 Bus Bar

- | | |
|--------------------|---|
| QQ-B-825
COPPER | For high-conductivity electrical parts, bus bars, etc. Similiar to ASTM B-187 or B-188. Specify material composition, type, class, and edge contours. |
|--------------------|---|

24.2.2.3 Rods, Shapes, Forgings, and Flat Products

- | | |
|-------------------------|--|
| QQ-B-626
BRASS | For machined parts and general fabrication. Specify composition, form, and temper required. |
| QQ-B-637
NAVAL BRASS | For use as bolts, nuts, turnbuckles, bushings, and machined parts. Good corrosion resistance. Specify composition, form, and temper required. Similiar to ASTM B-21. |
| QQ-B-679
AL BRONZE | Good strength, bearing qualities, and corrosion resistance. Similiar to ASTM B-150 or B-169, as applicable. Specify composition, form, temper, and finish. |

MATERIALS

24.2.2.3 (Contd)

QQ-B-750 For "flat" springs and electrical contacts. Specify composition,
PHOSPHOR form, and temper.
BRONZE

24.2.2.4 Sheet and Strip

QQ-C-576 For electrical parts, springs, and general fabrication purposes.
COPPER Specify form, temper, and composition.

QQ-B-613 For formed parts with good electrical conductivity.
BRASS

24.2.2.5 Shim Stock

MIL-S-22499 For use as shims in bearings, gear boxes, and mechanisms requiring
BRASS close adjustments. Made from QQ-B-613 Composition 2, 1/4-hard
Composition 2 temper or harder. Specify type and class.

24.2.2.6 Wire

QQ-W-321 For pins, springs, rivets, screws, etc. Similar to ASTM B-134.
BRASS Specify composition, shape, and temper.

QQ-W-343 For electrical and nonelectrical uses. Uninsulated solid round wire,
COPPER uncoated or tin-coated. Specify composition, temper, and coating.

QQ-W-401 Round wire for use as helical springs. Similar to ASTM B-159,
PHOSPHOR Alloy A.
BRONZE

MIL-W-5086 Electrical, 600V, aircraft.
COPPER

MIL-W-16878 Electrical, insulated, high temperature. Specify slash number, for
COPPER temperature and voltage.

24.2.2.7 Braid, Wire (Copper, Tin-Coated, Tubular)

QQ-B-575 Intended for use as electrical shielding for ignition and power and
COPPER lighting cables.

MATERIALS

24.2.2.8 Castings

QQ-B-671 High strength and hardness, excellent corrosion resistance, good
AL BRONZE wearing qualities. May be used for valve seats, bearings, bush-
ings, and bearing plates subjected to heavy loads. Specify
class and condition.

24.2.3 MAGNESIUM ALLOY (Reference: MIL-HDBK-693 (MR) Military
Standardization Handbook, Magnesium and Magnesium Alloys)

24.2.3.1 Bars, Rods, and Special-Shaped Sections, Extruded

QQ-M-31 General purpose usage, limited weldability, moderate mechanical
properties. Specify composition, temper form, protective finish.
Similiar to ASTM B-107.

24.2.3.2 Sheet and Plate

QQ-M-44 Good forming properties, weldable, not heat-treatable, moderate
mechanical properties. Specify temper and protective finish.
Similiar to ASTM B-90.

24.2.3.3 Castings

QQ-M-55 Mold castings with moderate mechanical properties; may be used
for intricate castings. Specify composition, temper, critical areas,
location of tests, and protective finish. Similiar to ASTM B-199.

QQ-M-56 Sand casting alloys not to be used for pressure-tight castings;
welding is not recommended. Specify alloy, temper, location
of tests, critical areas, and protective finish. Similiar to ASTM B-80.

24.2.4 STEEL (Reference: MIL-HDBK-5 Metallic Materials and Elements for Flight
Vehicle Structures)

24.2.4.1 Bar and Shapes

QQ-S-631 Special quality hot-rolled carbon steel used for general fabrication
Class 60 by machining, forming, or welding. Specify Grade 1020 if ordering
to chemistry, or class 60 if ordering to mechanical properties
(TS of 60,000 and Y PT of 30,000). Similiar to ASTM A-107,
Grade 1020, or A-306, Grade 60, respectively, or A-7 for shapes.

QQ-S-634 Similar to QQ-S-631 except that the material is cold finished.
Specification ASTM A-108 is a similar material. Specify
chemistry, such as 1018 or 1020. Compatible mechanical
properties may be specified.

MATERIALS

24.2.4.1 (Contd)

QQ-S-741	Low carbon steel bars and shapes for bridges, buildings, and general structural purposes. Grade A is similar to ASTM A-7 with minimum TS of 60,000 and Y PT of 33,000, but shall not be used for welding over 3/4 inch thickness. Grades B and C are similar to ASTM A-36, generally of slightly higher quality than Grade A, and with minimum TS and Y PT of 58,000 and 36,000 respectively.
MIL-S-5000 (4340)	This material, condition F, hardened and tempered, is used for larger sections and higher strength than 4140 allows. This condition has TS of 150,000 and Y PT of 130,000. Specifications ASTM A-322 and QQ-S-624 are similar materials. Specify condition and finish.
MIL-S-5626 (4140)	Similar to MIL-S-6758 (4130) except for higher carbon. Used for bolts, shafting, and high strength structural members. It has TS of 125,000 and Y PT of 103,000. Specifications AMS6382 and QQ-S-624 are similar materials. Specify condition and finish.
MIL-S-6758 (4130)	This material, condition F, hardened and tempered, is used for high strength structural members and for nitriding application. This material is weldable by the fusion method and is frequently used in the normalized condition. Condition F has TS of 125,000 and Y PT of 100,000. Specification QQ-S-624 is a similar material. Specify condition and finish.
QQ-S-763 STN'L ST'L 302,303	This material is a general-type, corrosion-resistant steel. This material, Condition A, has TS of 75,000 and Y PT of 30,000. Specification MIL-S-7720 is a similar material. Type 303 is a free machining grade.
QQ-S-763 STN'L ST'L 304L	This material is similar to 304 except it has a higher resistance to corrosion after welding when subsequent annealing is impractical.
QQ-S-763 STN'L ST'L 316,316L	This material is a superior corrosion-resistant material. For thick sections used in welding, use 316L. It has TS of 75,000 and Y PT of 30,000. Specification MIL-S-7720 is a similar material.
QQ-S-763 STN'L ST'L (347)	This material is a corrosion resistant material; it is weldable and does not require annealing after welding. Condition A has TS of 75,000 and Y PT of 30,000.
QQ-S-763 STN'L ST'L (431)	This material, condition A, is used primarily for its high mechanical qualities, such as structural parts, pump shafts, and valve parts. It is heat-treatable but is less corrosion resistant than the 300 series. This material has TS of 115,000 and Y PT of 90,000.

MATERIALS

24.2.4.1 (Contd)

QQ-S-763 This material, condition A and grade C, is used where extremely
STN'L ST'L high hardness and wear resistance are required, such as ball bearings,
(440) bushings, valve seats, etc.

24.2.4.2 Plate Sheet and Strip

QQ-S-698 This material, hot-rolled, is used for general fabrication where
 surface defects are not objectionable. Specifications ASTM
 A-415 and A-425 are similar materials. Specify quality and
 finish.

QQ-S-698 This material, cold-rolled, is suitable for exposed parts requiring
 a good surface finish. Specifications ASTM A-109 and -365
 are similar materials. Specify quality, temper, and finish.

MIL-S-7947 This material in the annealed condition is used primarily in the
(1095) manufacture of flat springs which are heat treated after forming.
 Specify condition 1, 2, or 3.

QQ-S-766 This material (1/2-hard) is used for corrosion-resistant struc-
STN'L ST'L tural parts. It is not suitable for gas or arc welding. It has
301 TS of 150,000 and Y PT of 110,000. Specify class and
 temper. Similiar to ASTM A-240 and MIL-S-5059.

QQ-S-766 This material, cold-finished, is intended primarily for structural
STN'L ST'L applications where welding is limited, and material in the annealed
304 condition is generally used for resistance to severe corrosion media.
 Specify composition, condition, temper, and finish. Similiar to
 ASTM A-240.

QQ-S-766 This material is similar to 304 except it has a higher resistance
STN'L ST'L to corrosion after welding when annealing is not practical. Similiar
304L to ASTM A-240. Specify composition, condition, temper, and
 finish.

QQ-S-766 This material in the annealed condition is a superior corrosion-
STN'L ST'L resistant material. This material is weldable; use 316L for
316,316L better corrosion resistance after welding. Specify composition,
 temper, and finish. Similiar to ASTM A-240.

QQ-S-766 This material (cold-rolled) is used primarily for exhaust stacks,
STN'L ST'L manifolds, and ring collectors. It is weldable and heat and
347 corrosion-resistant. Similiar to MIL-S-6721 and ASTM A-240.
 Specify composition, temper, and finish.

MATERIALS

24.2.4.3 Tubing

- MIL-T-5066 This material, either seamless or welded, is used primarily for
1025 applications not requiring high strength material. It has TS of
55,000 and Y PT of 36,000. Specifications (welded-type)
AMS 5077 and MIL-T-16343 and specifications (seamless)
AMS 5075 and MIL-T-16343 are similar materials.
- MIL-T-6736 This material is used for medium and high-strength structures and
4130 pressure tubing. Corrosion resistance is slightly better than low
carbon steel. It is weldable but requires preheat before welding
and stress relief after welding. Specifications QQ-T-825 (T.4130),
AMS 6360, 6361, and AMS 6362 are similar materials.
- MSFC-SPEC-131 This material, condition A and condition B (1/8-hard), is used
STN'L ST'L 304 for corrosion-resistant pneumatic, hydraulic, and cryogenic systems.
It is weldable, but for a higher degree of corrosion resistance use
304L or 316L. In condition A it has TS of 75,000 and Y PT
of 33,000 and in condition B (1/8-hard) it has TS of 105,000
and Y PT of 75,000. Specifications MIL-T-23226 and ASTM
A-269 are similar materials.
- MSFC-SPEC-131 This material is similar to 304 except that in condition A, the TS is
STN'L ST'L 65,000 and Y PT is 25,000. It has superior corrosion resistance
304L after welding than 304. Specifications MIL-T-23226 and
ASTM A-269 are similar materials.
- 10 MO 1734 This material (condition A, class 3, grade D) is used in fuel systems
STN'L ST'L and has greater corrosion resistance to pitting than 304. Speci-
316 fication ASTM A-269 is a similar material.
- MIL-T-23226 This material is corrosion resistant and weldable and should be
STN'L ST'L used when it is impractical to anneal after welding. It has TS of
347 75,000 and Y PT of 30,000. Specifications MIL-T-8606 and
ASTM A-269 are similar materials.

24.2.4.4 Pipe

- WW-P-406 This material, grade A, B, or C, is weldable and is primarily
Black or Galvan- used for general fabrication of structures and low pressure piping.
ized, Welded or Specification ASTM A-20 is a similar material.
Seamless
- WW-P-404 This material, grade A or B, is used primarily for close coiling
Black or Galvan- or cold bending. Specification ASTM A-53 is a similar material.
ized, Welded
or Seamless

MATERIALS

24.2.4.4 (Contd)

ASTM A-312 This material is used for general corrosive service and low temper-
STN'L ST'L atures to -325° F.
304,304L,316
Seamless or
Welded

24.2.4.5 Castings

QQ-S-681 This material, classes 65-35 and 70-36, is intended for welding.
CARBON Class 80-40 is used for parts subject to crushing stresses or
 surface wear. Classes 80-50, 90-60, 105-85, 120-95,
 150-125, and 175-145 are used where mechanical proper-
 ties are of prime importance. Specifications ASTM A-27 and
 MIL-S-15083 are similar materials.

24.3 NON-METALLIC MATERIALS

24.3.1 GLASS AND GLASS FIBER PRODUCTS

24.3.1.1 Glass

MIL-G-8602 Laminated, flat plate.

24.3.1.2 Glass Fiber Products

MIL-P-8013 A polyester, glass fiber base, low pressure laminate for structural
 applications such as fairings, radomes, or other structural parts.
 These laminates have a thermal capability from -100° F to approx-
 imately 225° F.

MIL-C-9084 Woven glass fabrics, cleaned and treated, and then finished for
 further fabrication into glass fabric base plastic laminates, con-
 forming to MIL-P-8013. May also be used without resin as a
 facing for insulating blankets where high temperature insulation
 or sound absorption is required.

MIL-Y-1140 Glass fiber tape and other forms used for edge trim of glass fiber
 insulation for lagging, and electrical insulation.

24.3.2 PLASTICS

24.3.2.1 Molded Parts, Rods, Sheet, Tube, and Extrusions

MIL-P-79 Laminated, thermosetting plastic rods and tubes for use as electrical
ROD AND TUBE insulation. Has good moisture resistance.

MATERIALS

24.3.2.1 (Contd)

MIL-P-17091 Rigid polyamide (nylon). A light, strong, tough plastic with good
MOLDED PARTS electrical properties. Resistant to sunlight, common solvents, and
RODS AND sea water.
SHEET
EXTRUSIONS

AMS 3651 Polytetrafluoroethylene (Teflon). Extreme chemical inertness.
MOLDED PARTS Very good dimensional stability. Nonflammable, heat-resistant
RODS AND up to 500° F. Good flexural strength, excellent machining
TUBE SHEET properties. Used for valve seats, packings, unlubricated seals,
and high frequency electrical insulation.

MIL-P-15037 Laminated, glass cloth melamine resin plastic thermosetting sheet
SHEET materials for use as electrical insulating material for services
under moisture conditions.

MIL-I-631 Synthetic resin, flexible tubing for use as electrical insulation on
TUBE wire, bus bars, etc.

MIL-I-22129 Polytetrafluoroethylene (Teflon). For use as flexible insulation
TUBE tubing or sleeving. High temperature.

MIL-I-7444 Vinyl plastic tubing for use as flexible conduits. Low temperature.
TUBE

**24.3.3 RUBBER (Reference: MIL-HDBK-149A Military Standardization Handbook,
Rubber and Rubber Like Materials)**

24.3.3.1 Synthetic Rubber, Sheet, Molded and Extruded

MIL-R-6855 Buna-N. Has good fuel and oil resistance. It will be satisfactory
CLASS I in places where solvent and water resistance, along with good
abrasion properties, are required. Not recommended for parts that
will be exposed to sunlight and ozone, or where high dielectric
strength is needed.

MIL-R-6855 Neoprene. Can be used in applications where the part will be
CLASS II exposed to sunlight, ozone, engine oil, and abrasive action.
It has better compression set than Class I and can withstand in-
termittent exposure to jet fuel. Unsuitable for applications where
there will be temperature extremes because the brittle point is
-67° F, also unsatisfactory where there will be long exposure to
water, solvents, and aromatic oils.

MATERIALS

24.3.3.1 (Contd)

- MIL-C-3133 Nitrogen-blown sponge rubber. Specify base material. Has physical properties similar to Buna-N, if Buna-N specified.
- MIL-R-5847
CLASS I Silicone rubber. Intended for applications where extreme low and medium high temperatures, low compression set, and ozone resistance are required. Can be bonded to itself and other materials. It is a general purpose silicone that can be used in applications where resistance to abrasion, tear, aromatic oils, fuels, and solvents are not required.
- MIL-R-5847
CLASS II Same applications as Class I except material does not have as low an operating temperature; however, it does have higher operating temperatures.

24.3.3.2 Synthetic Rubber Hose

- MIL-H-7061 Flexible, self-sealing fuel hose for aromatic fuel lines.
- MIL-H-13444 Automotive applications, fuel, and oils.

24.3.3.3 Synthetic Rubber Gaskets

- MIL-G-6183 Synthetic rubber and cork composition sheet for use with aromatic fuels and lubricants up to 200⁰ F where low contact pressures, curved surfaces, and surface irregularities are to be sealed.
- MIL-A-7021 Compressed asbestos sheet, synthetic rubber-bonded, for cut gaskets for use where low compressibility, heavy rigid flat surfaces, and high bolt pressure are contributing factors, as in heavy flanges in power plant systems.

MANUFACTURING PRACTICES AND TOLERANCES

25:1 DIMENSION AND TOLERANCE INTERPRETATIONS

KSC-STD-168 Drawing Terms and Tolerances, Interpretations of, is to be used in conjunction with Sections 5 and 8 of this manual in the preparation of drawings.

The information contained in KSC-STD-168 is not intended to influence design features or tolerances, but to interpret features and tolerances implied by delineation and not specifically stated on the drawing.

When design requirements require closer control, permit more liberal tolerances, or more economical procedures, than those established by KSC-STD-168, the specific requirements should be clearly stated on the drawing.

When the requirements of KSC-STD-168 provide adequate control, this document may be referenced on the drawing by note. For standard note, see Section 9. In this case, all such procedures as burring, tool relief, etc., or form tolerances such as squareness, straightness, concentricity, etc., adequately defined and/or controlled by KSC-STD-168, shall be omitted from the drawing.

SHEET METAL

26.1 GENERAL REQUIREMENTS

The recommendations included in this Sheet Metal Section are for low-cost and low-production parts.

Occasionally there will be design problems which will force closer tolerances. These exceptions should be carefully examined and kept to a minimum to reduce costs. Wherever possible, broader tolerances than those shown in this section should be incorporated on the drawings.

Two-place max/min dimensions should generally be used for sheet metal designs. Steel scales and simple measuring equipment will then be used for manufacturing and inspection, resulting in the lowest possible cost. As more complicated devices must be used for three - and four-place dimensions, the cost will be considerably higher.

Drill plans for an electrical connector or other component may indicate tolerances not in accordance with this section. These tolerances should then be reviewed as to whether or not standard tolerances may be substituted. It will then be possible to use a "cluster die" or a Wiedemann Type Press to produce the part.

For economical low production parts, it is good practice to punch all holes "in the flat" and then follow with any bending and welding operations.

A squareness or flatness requirement should be carefully examined. Most designs do not need these requirements as the parts are usually secured in an assembly and will change shape in the final configuration.

Whenever possible, irregular shaped holes should be oriented in the same direction.

Consistency of design is very important. Hole diameters should be as uniform as possible. Radii, notches, bends, etc. should also be consistent.

When drawings are made of fitted parts or assemblies, such as a box and a cover, each drawing should cross-reference the other drawing number.

26.2 RECOMMENDED TOLERANCES AND DIMENSIONING

For low-cost, low-production parts, the base line should not be referenced from a bent edge. The base line should generally coincide with the set of holes nearest a bent edge. (See Paragraph 26.8, pg. 26-13.) It may be occasionally advantageous to use a machine surface or the center line of a part, where symmetry is important, as the base line.

Figure 26-1 illustrates minimum tolerances to be followed for low cost, low production parts.

SHEET METAL

26.2 (Contd)

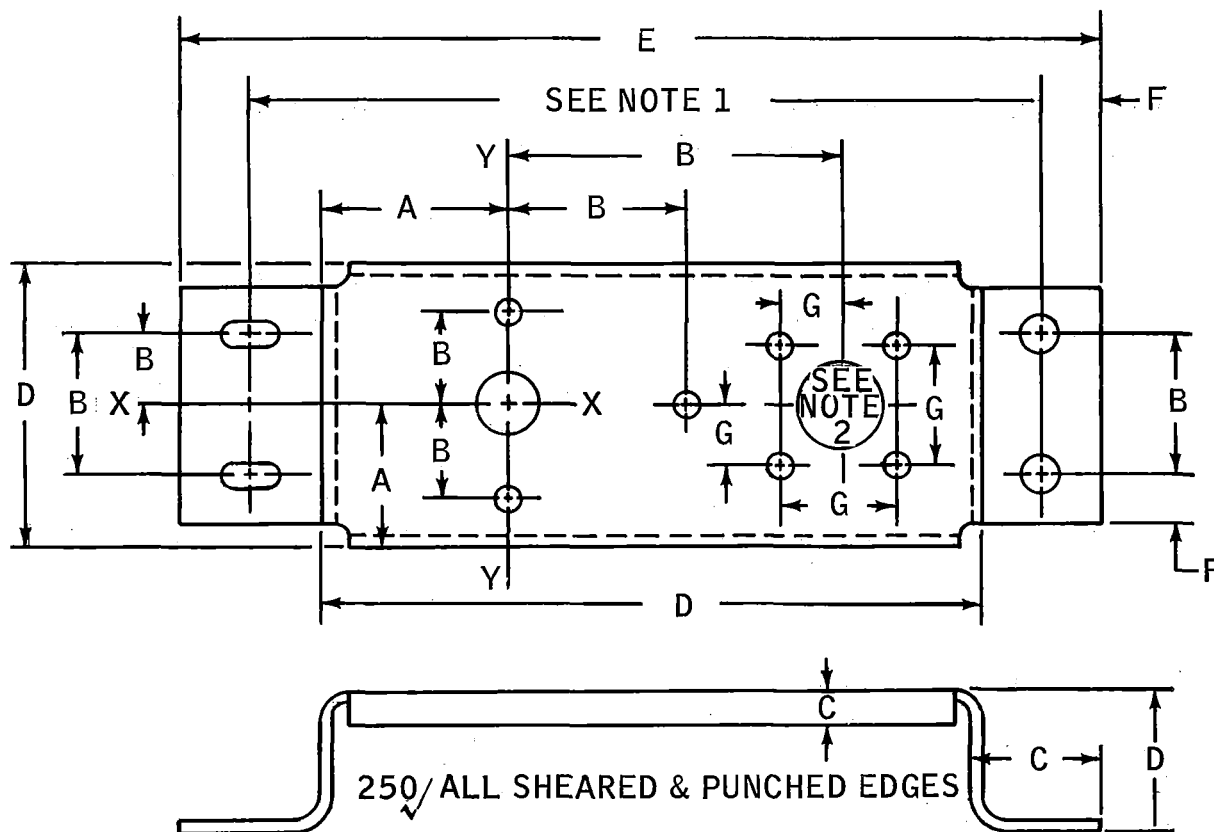


Figure 26-1

DIM.	DESCRIPTION AND MINIMUM TOLERANCE	
A	BEND TO HOLE	$\pm.02$ to 8 Lg, $\pm.03$ over 8
B	HOLE TO HOLE	$\pm.01$
C	BEND TO END OF FLANGE	$\pm.03$
D	OVER TWO BENDS	$\pm.03$ for each 12" length
E	OVERALL (WITH BENDS)	$\pm.03$ to 6 Lg, $\pm.04$ from 6 to 12, over 12 $\pm.06$
F	HOLE CENTER TO CUT EDGE	$\pm.01$
G	LOCATION OF HOLES IN A DRILL PLAN FOR A COMPONENT $\pm.007$	

- NOTES: 1. Use of punched slots on one end eliminates necessity of tight tolerance between mounting holes.
2. Use coordinate dimensions to locate a series of related punched holes.

SHEET METAL

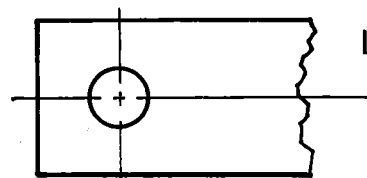
26.3 BLANKING DESIGN

26.3.1 DIRECTION OF GRAIN

If the functioning of the part requires a specific grain direction, it should be indicated on the drawing. In most cases, the direction of the grain can be as much as 45° from the theoretically ideal direction (perpendicular to the bend) before trouble would occur during the bending operation. In view of this, a permissible variation is generally indicated, since this allowance is often necessary to permit economical material utilization.

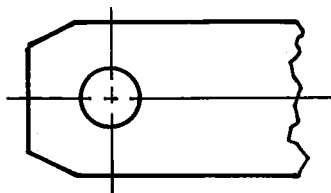
26.3.2 ENDS OF BLANKED (Or Sheared) PARTS

Square, sheared ends will provide the lowest cost for low-production use. Other choices are illustrated below:

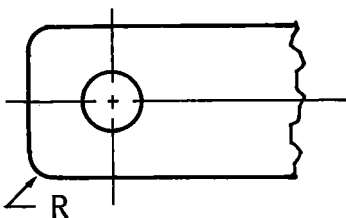


LOWEST COST FOR LOW PRODUCTION

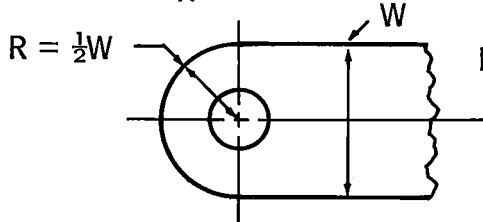
← BREAK SHARP CORNERS



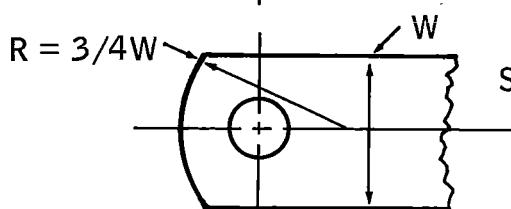
NEXT LOWEST COST FOR LOW PRODUCTION



HIGHEST COST FOR LOW PRODUCTION



LOWEST COST FOR HIGH PRODUCTION



SECOND CHOICE FOR HIGH PRODUCTION

 SHEET METAL

26.3.3 INTERNAL BLANKED CORNERS

In order to avoid square corners on punches and dies, the following radii are established for internal blanked corners:

Up to and including .07 stock----- .05 - .08 radius
 Above .07, to and including .13 stock ---- .12 - .15 radius

26.3.4 SIZE OF HOLES

It is recommended that the basic diameter of holes be in accordance with standard drill sizes and tolerances in accordance with Table 26-1. The use of punched holes of a diameter less than the stock thickness is impractical.

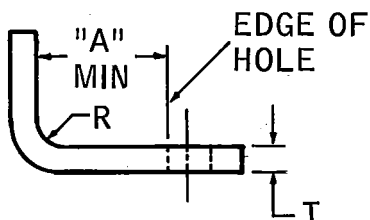
Table 26-1. Standard Drill Sizes and Tolerances

DRILL SIZE	NOMINAL DIA	MIN-MAX LIMITS (METALLIC)	TOL RANGE
#60	.0400	.039 - .042	+.002 -.001
#50	.0700	.069 - .073	+.003 -.001
#39	.0995	.098 - .104	+.004
#32	.1160	.115 - .120	-.001
#30	.1285	.128 - .132	
#28	.1405	.138 - .146	+.005 -.002
#27	.1440	.142 - .149	
#23	.1540	.152 - .159	
#22	.1570	.155 - .162	
#18	.1695	.168 - .174	
# 9	.1960	.194 - .201	
# 3	.2130	.211 - .218	
# 2	.2210	.219 - .226	
# 1	.2280	.226 - .233	+.006 -.002
(B)	.2380	.236 - .244	
(C)	.2420	.240 - .248	
1/4	.2500	.248 - .256	
9/32	.2812	.279 - .287	
5/16	.3125	.310 - .318	
23/64	.3594	.357 - .365	
3/8	.3750	.373 - .381	
13/32	.4062	.404 - .412	
27/64	.4219	.420 - .428	
7/16	.4375	.436 - .444	+.008 -.002
1/2	.5000	.498 - .506	
9/16	.5625	.560 - .570	
5/8	.6250	.623 - .633	
11/16	.6875	.686 - .696	+.010 -.003
3/4	.7500	.748 - .758	
13/16	.8125	.810 - .822	
7/8	.8750	.870 - .885	
15/16	.9375	.934 - .948	
1	1.0000	.997 - 1.010	

SHEET METAL

26.3.5 DISTANCE FROM EDGE AND BETWEEN HOLES

The following general rules should be observed to minimize the distortion in sheet metal caused when holes are pierced too close to an edge, to other openings, or to a bend.



MINIMUM DISTANCE OF METAL FROM HOLE TO EDGE OR TO ANOTHER HOLE = $2T$

"A" MINIMUM FROM HOLE
 $1\frac{1}{2}$ " DIAMETER AND LARGER = $\frac{3T}{2} + 2R$ MAX
 TO BEND

"A" MINIMUM FROM HOLE SMALLER THAN
 $1\frac{1}{2}$ " DIAMETER TO BEND = $\frac{3T}{2} + R$ MAX

26.3.6 LIGHTENING HOLES

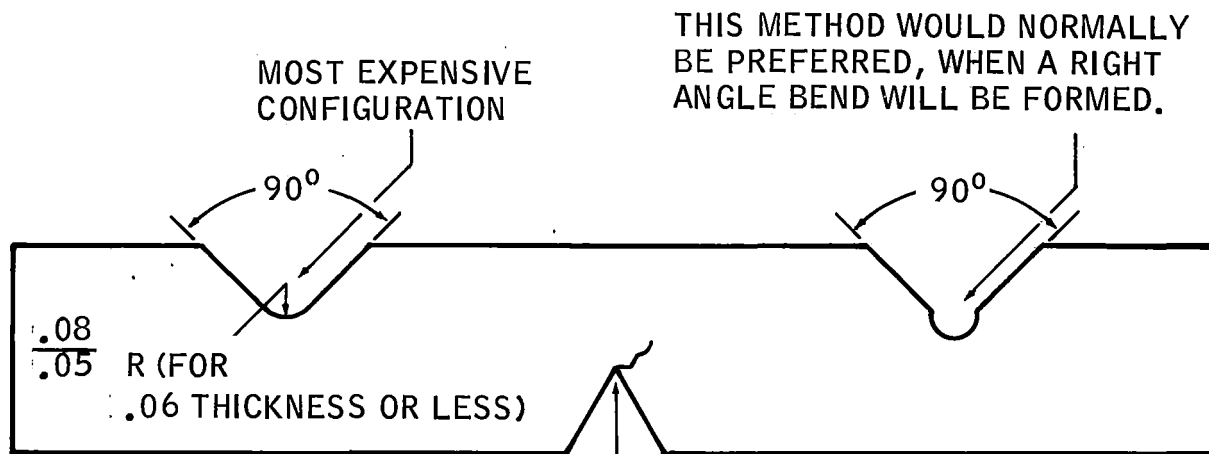
The use of lightening holes should be carefully examined, as the actual weight saved, in many cases, is extremely small and may not justify the added cost.

26.4 SHEARING DESIGN

26.4.1 NOTCHING

Notches may be required in the edge of a part for functional reasons, such as providing clearance for attachment, locating means, etc., or they may be required as a relief to facilitate forming.

Normally, all notches should include 90° . Several choices are illustrated below:

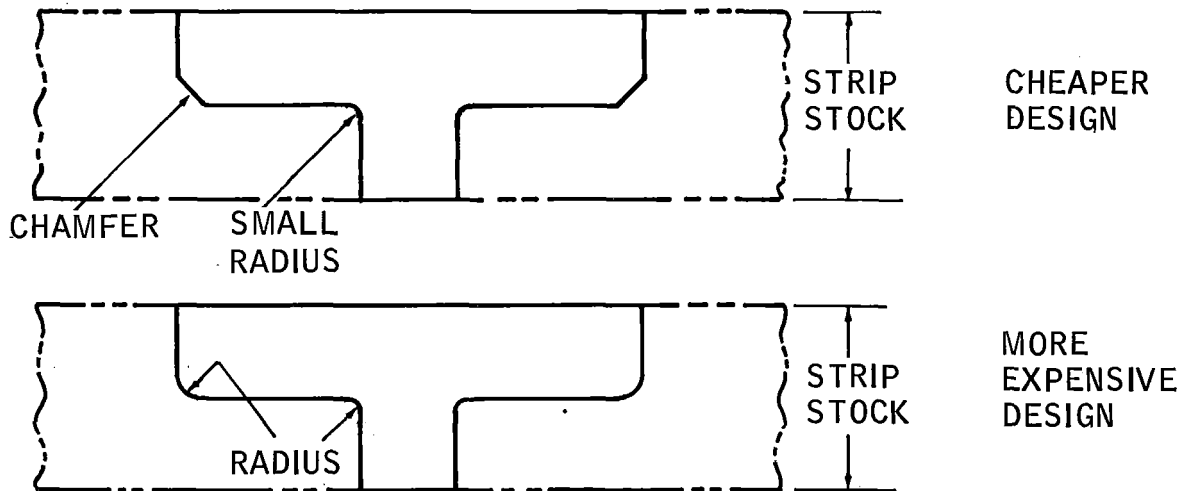


ALTHOUGH THIS IS THE CHEAPEST CONFIGURATION,
 A SHARP VERTEX IS NOT RECOMMENDED
 SINCE TEARING MAY START AT THIS
 POINT.

SHEET METAL

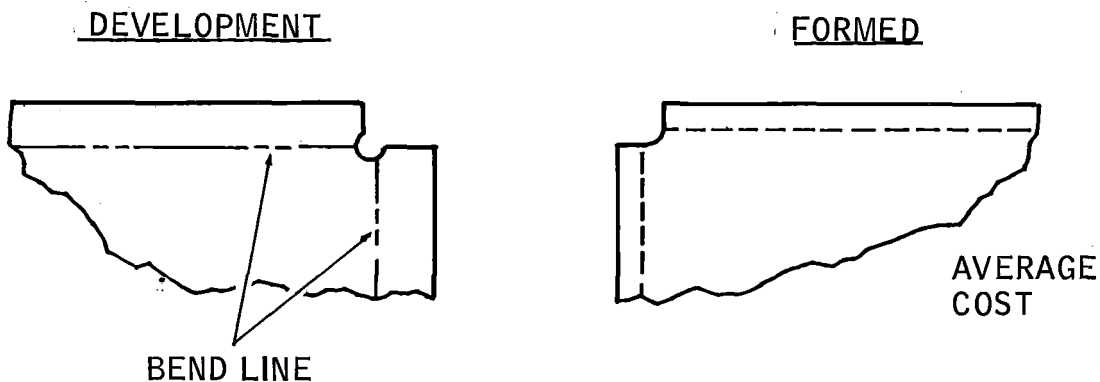
26.4.2 CUTTING OFF

When designing parts to be cut from strip stock, consideration should be given to the illustrations below:



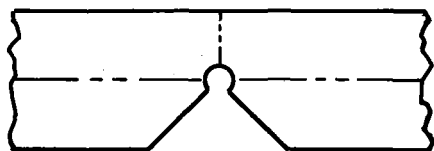
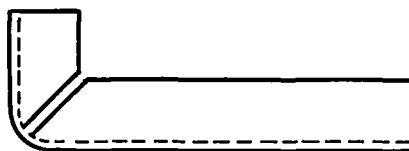
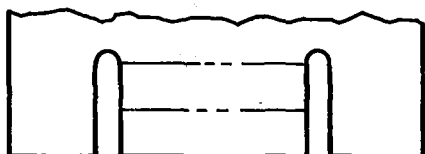
26.4.3 PREFERRED DESIGNS

Preferred designs of corner notches and cut-outs for flanges are shown below:



SHEET METAL

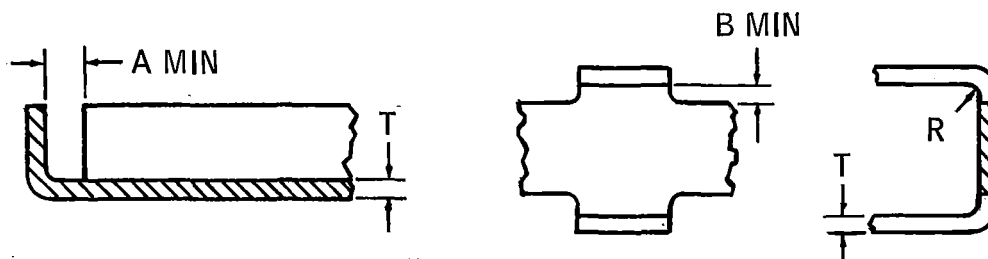
26.4.3 (Contd)

DEVELOPMENTFORMEDAVERAGE
COSTPREFER
1/8" INCREMENTS3X MATERIAL
THICKNESS WITH
MINIMUM OF .1226.5 FORMING DESIGN

Forming processes consist of bending, drawing, flanging, folding, twisting, off-setting, embossing, or otherwise shaping a portion of a blank.

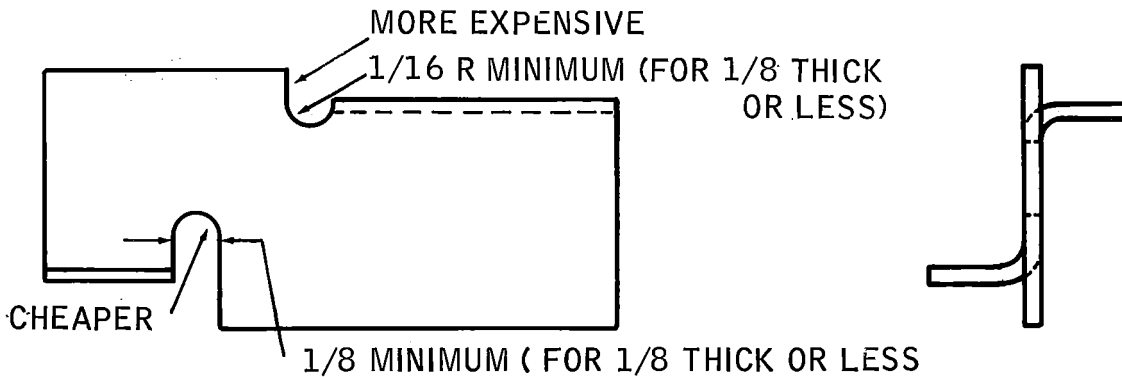
26.5.1 CLEARANCE AT BENDS

On formed parts, clearance at the bends should be provided so that there is no edgewise metal interference to prevent the tools from producing a satisfactory bend. (See below.) When flanges extend over only a portion of a part, a relief should be provided to eliminate tearing. (See below.)

MINIMUM CLEARANCE $A = 2T$ MINIMUM CLEARANCE $B = \text{RADIUS OF BEND} + T$

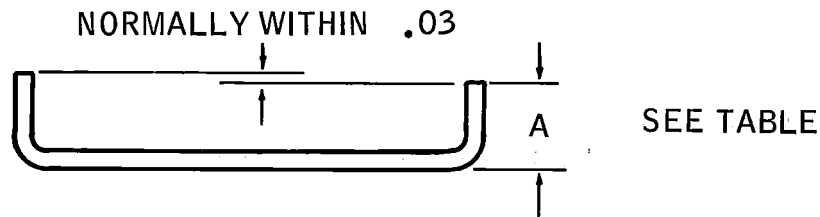
SHEET METAL

26.5.1 (Contd)



26.5.2 MINIMUM LENGTH FOR SHORT BENDS

When short bends are required, the height of bend should be determined from the table below. Bends shorter than those shown are more costly, as the operation cannot be accomplished on a Press Brake.



MATERIAL THICKNESS	MINIMUM LENGTH A
.000-- .020	.17
.021-- .025	.20
.026-- .040	.23
.041-- .051	.27
.052-- .072	.35
.073-- .080	.38
.081-- .090	.42
.091-- .102	.54
.103-- .114	.73
.115-- .128	.86
.129-- .182	1.10
.183-- .257	1.23

SHEET METAL

26.5.3 VARIATION FROM RIGHT ANGLE BENDS

The angular variation in right angle bends will vary according to the material, thickness, thickness variation, hardness, etc. The maximum variations permitted, unless otherwise specified on the drawings, should not exceed $+1.5^{\circ}$ or -1° (per KSC-STD-168).

26.5.4 MINIMUM DISTANCE BENDS

For low-cost Press-Brake work, the minimum distance between bends is shown below.



MATERIAL THICKNESS "T"	LENGTH "A"
.000 to .040	.51/.43
.041 to .072	.63/.55
.073 to .125	1.29/1.21

When the design requires, length "A" may be reduced to 5T, with higher cost.

26.5.5 MINIMUM BEND RADII

There is considerable variation in the recommendations as to the minimum allowable bend radii for aluminum. The absolute minimum depends upon the condition of the material, the bending method, equipment used, and the angle of the bend. The following is included as a practical guide for average work and shows the minimum bend radius for bends, to and including 90° , that can be formed in aluminum without cracking the material. Minimum bends should not be used unless necessary; however, all bend radii should be selected from the table.

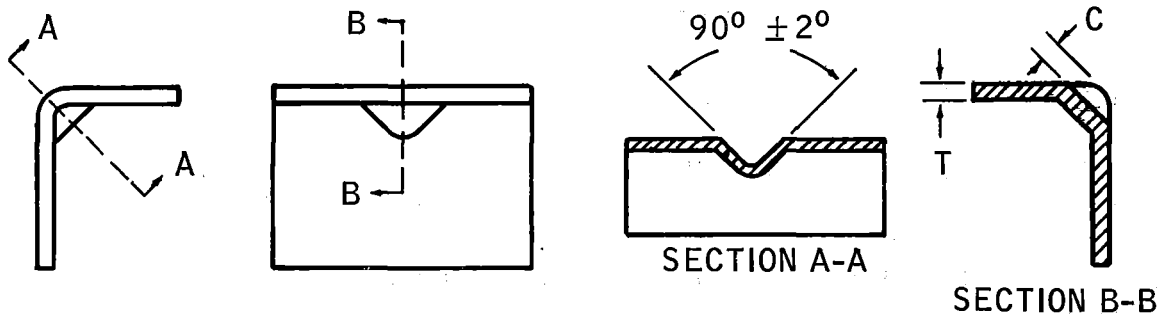
SHEET METAL

26.5.5 (Contd)

COM L DESIG- NATION	MINIMUM BENDING RADII FOR INDI- CATED MATL THICKNESS, INCH			
	.032	.063	.090	.125
AA-6061-0	$\frac{.04}{.03}$	$\frac{.04}{.03}$	$\frac{.07}{.05}$	$\frac{.07}{.05}$
AA-5052-H34	$\frac{.04}{.03}$	$\frac{.10}{.08}$	$\frac{.20}{.18}$	$\frac{.26}{.24}$
AA-6061-T6	$\frac{.04}{.03}$	$\frac{.10}{.08}$	$\frac{.20}{.18}$	$\frac{.26}{.24}$

26.5.6 GUSSETS (INTEGRALLY FORMED) FOR BENDS

If necessary, an embossed form may be incorporated into the design to increase rigidity and maintain accuracy of "Angle of Bend." It may also be employed as a stiffener in applications where an additional gusset might otherwise be required. (See below.)



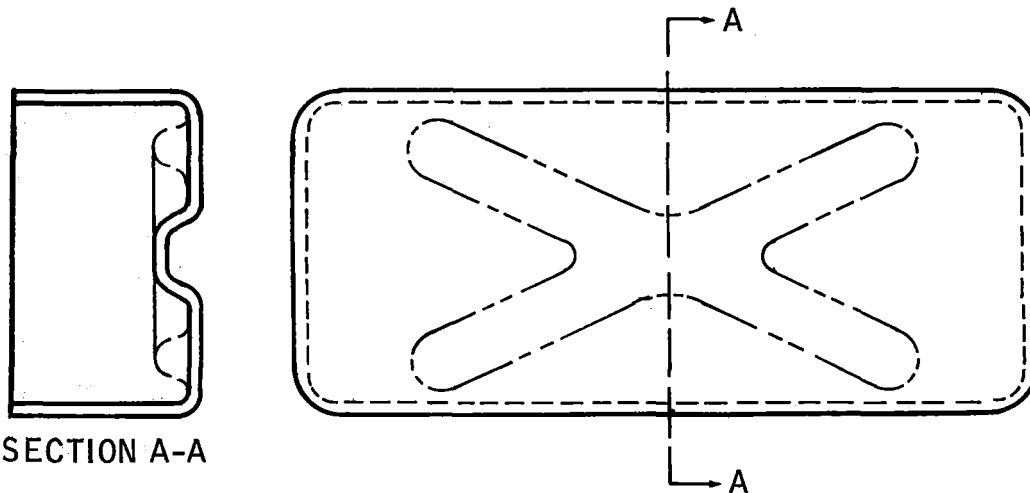
T	C ± .020
.032	.06
.050	.08
.063	.09
.080	.10
.090	.11

Ground Support Equipment

SHEET METAL

26.5.7 STRENGTHENING BEADS (CORRUGATIONS)

Strengthening beads should be formed in the same direction, relative to the surface of the part, as the outer flanges (if any) to facilitate tooling (see below). As special dies are required to form these shapes, they should be avoided whenever practical.



26.5.8 COINING

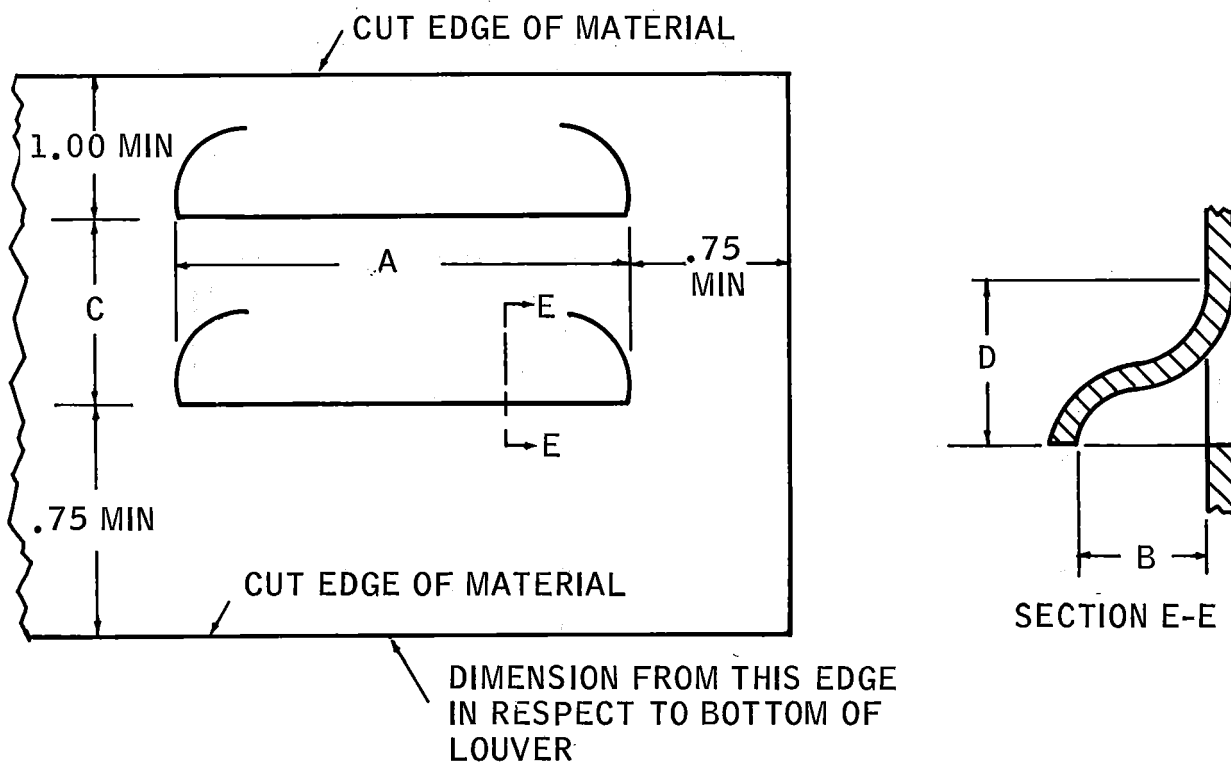
Coining is a process by which metal is made to cold flow by the application of extreme pressure. This contrasts with the drawing operation in which the metal is drawn over a form. In coining, the metal thickness is decreased in some areas when the metal flows away from these areas and increased in the areas into which the metal is forced.

Where wires and cables are fed through holes in sheet metal less than 1/8" thick, the holes shall be equipped with suitable grommets or punched and rolled for mechanical protection of insulation otherwise subject to abrasion.

In sheet metal from .050 to .125 thick, the hole edges should be rolled by coining or other means.

SHEET METAL

26.5.9 LOUVERS



A MAX	"B" (ALUMINUM & STEEL)			C MIN	D
	.032THK	.063THK	.090THK		
1.750	$\frac{.235}{.203}$	$\frac{.234}{.172}$	$\frac{.188}{.094}$	1.000	.375
3.000	$\frac{.329}{.297}$	$\frac{.312}{.250}$	$\frac{.297}{.203}$	1.000	.500
4.000	$\frac{.282}{.250}$	$\frac{.281}{.219}$	$\frac{.219}{.125}$	1.000	.500

SHEET METAL

26.6 BURRS

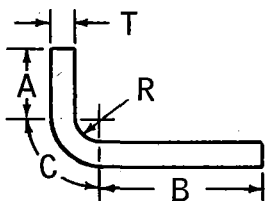
A burr is the undesired displacement of metal caused by certain manufacturing operations. It is a sharp, uneven projection at the edges and corners of a part.

Burrs and sharp edges must be removed.

26.7 FORMULA FOR CALCULATING SHEET METAL DEVELOPMENTS

This formula is for 90° bends using power bending brakes.

Developments are not to be shown on drawings. The developed dimensions will be given as approximate, as an indication of the amount of material required. Do not use for drawn or spun parts.



$$C = \frac{\pi}{2} (R + .42T)$$

$$\text{DEVELOPED LENGTH} = A + B + C$$

26.8 DRAWINGS

This paragraph should apply to all sheet metal parts, produced in the flat, containing eight or more holes. It should also apply to formed parts meeting above conditions where required tolerances, necessary for forming, are compatible.

Flat parts containing less than eight holes, or formed portions of parts containing less than eight holes, may be dimensioned in the conventional manner.

When employing "Base-Line" dimensioning (Figure 26-2), all holes shall be located from a horizontal reference line denoted "X-X" and a vertical reference line denoted "Y-Y". The X-X base line shall coincide with the horizontal center line of the uppermost hole in the part and shall preferably parallel the longest side of the part. The Y-Y base line shall coincide with the vertical center line of the hole nearest the left-hand edge of the part. Avoid the use of cut or formed edge as a base line.

Center lines of holes and other locating points should, whenever possible, be located on the .10 grid.

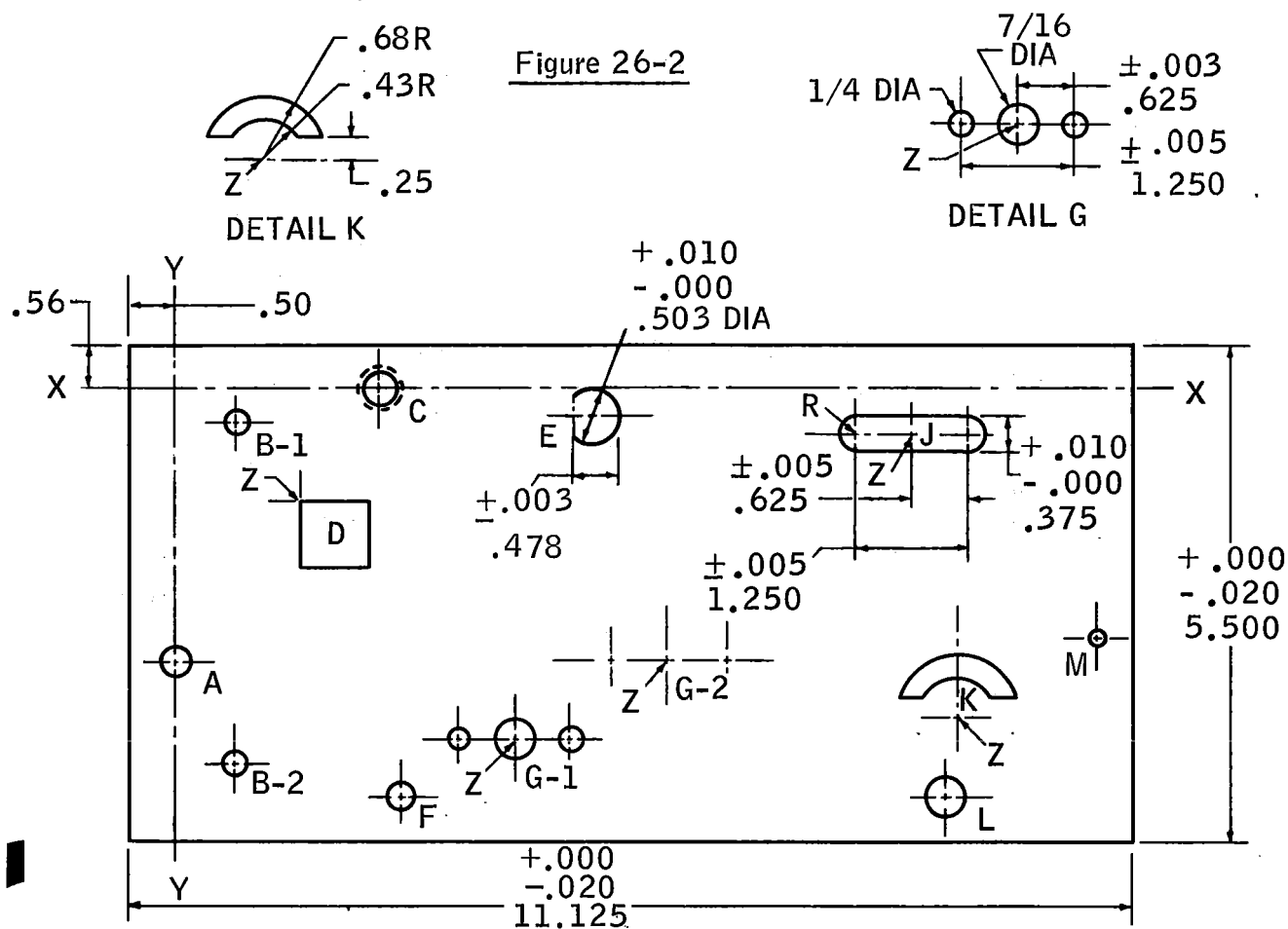
26.8 (Contd)

Irregular shaped openings shall have the intersection of their locating dimensions designated by the symbol "Z". The "Z" point for rectangular openings shall be the point nearest the X-X and Y-Y base line.

Locating dimensions from base lines X-X or Y-Y shall be the nominal dimension with tolerances indicated in the space provided adjacent to the title block. Should a closer tolerance be required, it shall be so designated in the tabulation using the "+" and "-" symbols.

Shear or cutoff dimensions shall show the maximum as the nominal with a minus (-) tolerance only (+.000).

- NOTES: 1. Tabulated dimensions are taken from base lines X-X and Y-Y and locate the center of indicated holes.
2. "Z" indicates the point of intersection of dimensions from X-X and Y-Y base lines.
3. Tolerance on two-place decimal dimensions shall be $\pm .010$.





SHEET METAL

26.8 (Contd)

SYMBOL	DISTANCE FROM Y-Y	DISTANCE FROM X-X	DESCRIPTION
A	.00	2.93	5/16 DIA
B-1	.68	.31	1/4 DIA
B-2	.68	4.12	
C	2.25	.00	# V DIA & CSK 82° + 0 - 2° x .401 + .010 -.000 DIA
D	1.37	1.18	.75 x .75
E	4.62	.31	SEE DETAIL
F	2.25	4.46	.217 + .004 - .000 DIA
G-1	3.75	3.84	SEE DETAIL G
G-2	5.50	3.00	
J	8.18	.43	SEE DETAIL
K	8.68	3.59	SEE DETAIL K
L	8.59	4.46	7/16 DIA
M	10.18	2.71	# 10 DIA

26.8.1 EAR AND SLOT CONFIGURATION: (For Dip-Braze Self-Fixturing)

EARS: Ears shall be .200 $\begin{smallmatrix} +.000 \\ -.020 \end{smallmatrix}$ long by .200 $\begin{smallmatrix} +.000 \\ -.040 \end{smallmatrix}$ high.

SLOTS: Slots shall be .250 $\begin{smallmatrix} +.020 \\ -.000 \end{smallmatrix}$ long. The width of the slots shall be determined by adding .004 to the nominal stock thickness. This width shall then be specified with a $\begin{smallmatrix} +.008 \\ -.000 \end{smallmatrix}$ tolerance.

LOCATION: Both the ears and the slots are to be located individually from the two axes with a tolerance of $\pm .010$.

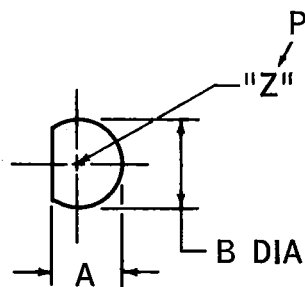
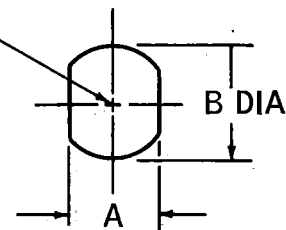
NOTE: A maximum of three ears (in line) should be used. More ears can be used if requirements demand; however, experience has shown that three ears are usually sufficient.

26.8.2 IRREGULAR SHAPE PUNCHED HOLES:

NOTE: When using irregular shape holes, it is most important that consistency be maintained in direction. Any variation requires a duplicate punch or changing the setup of the existing punch. Although it is preferred that these holes be positioned in increments of 90° in respect to the axes, 45° increments may be accommodated.



26.8.2 (Contd)

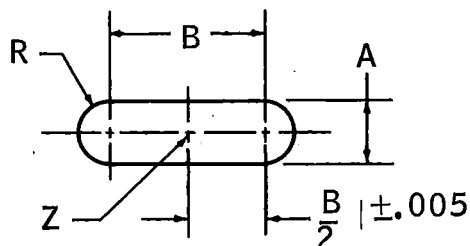
"D" HOLESOBLONG HOLES

A	B	A	B
$\pm .003$	$\pm .005$	$\pm .005$	$\pm .005$
.173	.197	.590	.630
.223	.257	.600	.650
.233	.257	.717	.770
.348	.380		
.478	.508		

A	B
$\pm .005$	$\pm .005$
.265	.322
.400	.453
.450	.510

26.8.3 ELONGATED HOLES:

Per Figure 26-2



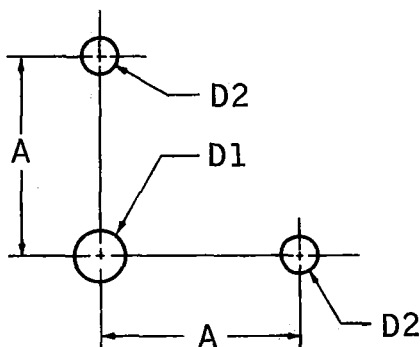
SCREW SIZE	"A"	"B" $\pm .005$
2	$\begin{matrix} +.005 \\ .115 \\ -.000 \end{matrix}$.095
4	$\begin{matrix} +.008 \\ .138 \\ -.000 \end{matrix}$.095
6	$\begin{matrix} +.006 \\ .168 \\ -.000 \end{matrix}$.095
8	$\begin{matrix} +.007 \\ .194 \\ -.000 \end{matrix}$.095
10	$\begin{matrix} +.007 \\ .219 \\ -.000 \end{matrix}$.095

NOTE: The "B" dimension may be readily extended to suit design requirements by moving the work with successive strokes of the punch. The tolerance shown above for the "B" dimension applies to the opening produced by one stroke of the punch. When the "B" dimension is extended, increase the tolerance to " $\pm .010$ ".

SHEET METAL

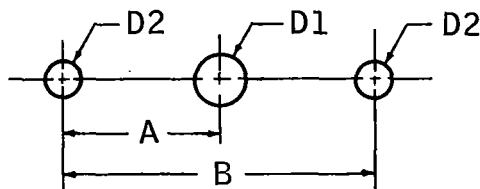
26.8.4 HOLE CLUSTERS

ANCHOR NUTS, SELF LOCKING - CORNER



PART NO.	DASH NO.	A $\pm .005$	D1	D2
NAS 698	1-04L	.203	.138- .146	.098- .104
	2-06L	.218	.168- .174	
	3-08	.234	.219- .226	
NAS 698	-3	.250	.279- .287	.098- .104

ANCHOR NUTS, SELF LOCKING - TWO LUG (REDUCED SIZE)



PART NO.	DASH NO.	"A" $\pm .005$	"B" $\pm .005$	"D1"	"D2"
NAS 697	-04L	.203	.406	.194- .201	$\frac{.104}{.098}$
NAS 697	-06L	.218	.437	.219- .226	$\frac{.104}{.098}$
NAS 697	-08	.234	.468	.248- .256	$\frac{.104}{.098}$
NAS 697	-3	.250	.500	.279- .287	$\frac{.104}{.098}$

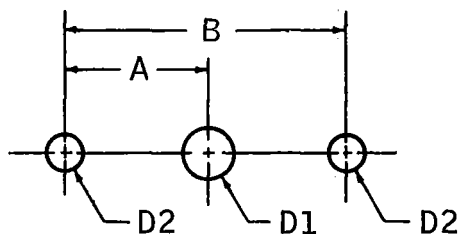


Ground Support Equipment

SHEET METAL

28.8.4 (Contd)

ANCHOR NUT, SELF LOCKING - TWO LUG



PART NO.	DASH NO.	"A" $\pm .005$	"B" $\pm .005$	"D1"	"D2"
AN361	832	.344	.688	.248- .256	$\frac{.104}{.098}$
AN361	1032	.344	.688	.279- .287	$\frac{.104}{.098}$



FORGINGS

27.1 GENERAL

Any part made by applying pressure to form either hot or cold metal to the desired shape, with or without the aid of special metal dies, may be considered a forging. The principal reason for selecting a forged part is to obtain mechanical properties not possible in castings. Other considerations, such as weight, cost, surface finish, weldability, etc., may also be factors in selecting a forging.

27.2 GENERAL DESIGN INFORMATION

The purpose of this section is to present information and hints to obtain the best design for forging.

27.2.1 DIE FORGINGS

The drop-hammer and press-forging processes are the most versatile for production of a large number of identical forgings from steel, aluminum, magnesium, and copper alloys. For production quantities, the finish-machined part is generally less expensive when machined from a die forging rather than from other types of forgings or bar stock.

27.2.1.1 Advantages

- a. Forging is usually chosen as a method of making small parts because it results in equal or greater strength at lower unit weight than is produced by castings or other methods of fabrication.
- b. Forging is capable of greater consistency of performance than many casting processes.
- c. Forgings, properly made, are free of internal defects. The process plus careful die design avoids mechanical defects. In addition, there are no blow holes or porosity areas common in castings.
- d. Usually there is a minimum of surplus to be removed by machining.
- e. Cost of die forgings is comparable to those of castings in carbon or alloy steel when the same compositions are used.



FORGINGS

27.2.1.2 Limitations

- a. Many intricate and cored shapes cannot be forged. These same shapes can be cast.
- b. Die costs are higher for die forging than for the complementary needs in most of the casting processes.
- c. Sizes that can be forged in closed dies are limited.
- d. Hot working of the metal requires less power, but frequently causes scaling and makes the holding of tolerances difficult.
- e. Holes in two planes would make the removal of a forging from the die impossible.
- f. Production of forgings is limited due to the fact that a steam hammer is limited to about 300 blows per minute.

27.2.1.3 Design Considerations

- a. Sections of forgings should be balanced about the parting line which should be located so that little or no side thrust is imparted to the dies. This is done by placing them at right angles to the direction of the die thrust wherever possible.
- b. Draft provision, such as shown in 27.2.1.4, should be adhered to unless design of the forging is such that less draft will not interfere with easy removal of the finished forging.
- c. Radii and fillets are used in forgings to cause changes in the flow of the metal being formed. Thus they should be as large as possible. Sharp corners tend to cause forging defects and die wear. Corner radii should be liberal due to the difficulty of filling small corners. Pressures tend to concentrate at sharp corners and help to develop die cracks that grow rapidly.
- d. Pockets and recesses should be avoided unless absolutely necessary. Depressed areas in forgings require raised sections in the die. Raised die sections tend to restrict the free flow of metal.

FORGINGS

27.2.1.3 (Contd)

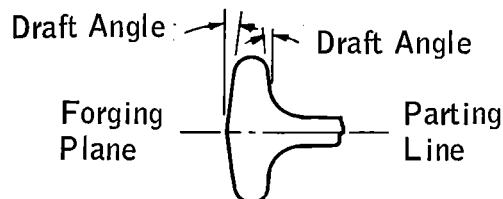
When die sections are thin or high, they are subject to bending and will wear rapidly as the result of being heated to a higher temperature than the remainder of the die. When pockets and recesses are required, sweeps and radii should be ample and maximum draft provided.

- e. Small holes should not be forged into the pieces. It is more economical to drill them later.
- f. Ribs, when provided, should be as low and as wide as possible. The rib top should have a full radius when possible and draft angles should also be as generous as possible.
- g. Dimensional tolerance should be as generous as possible.
- h. Metals may be as much as 5 percent stronger in tension along the grain fibers and have the ability to resist shock and impact to a much greater degree than across grain direction. Whenever possible, forgings should be designed to take advantage of the grain direction of the forge billet.

27.2.1.4 Draft Angle

A draft angle is the angle between a forged surface and a plane parallel to the direction of die motion. Draft normally originates from the parting line.

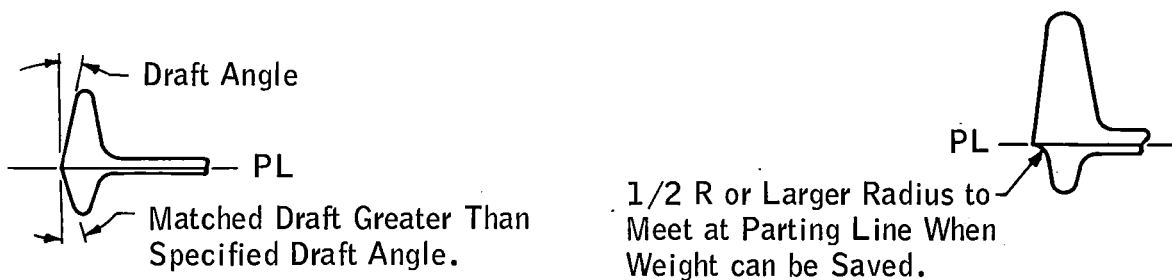
- a. The normal draft angle for aluminum and magnesium forgings is 5° . The normal draft angle for steel and titanium forgings is 7° . Exceptions to the normal draft angle are shown in the following paragraphs. Smaller draft angles are possible in specific applications.



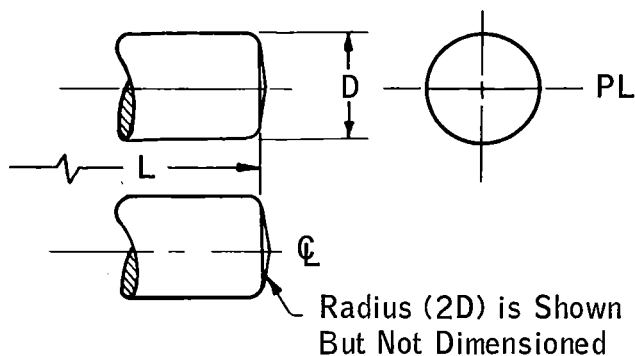


27.2.1.4 (Contd)

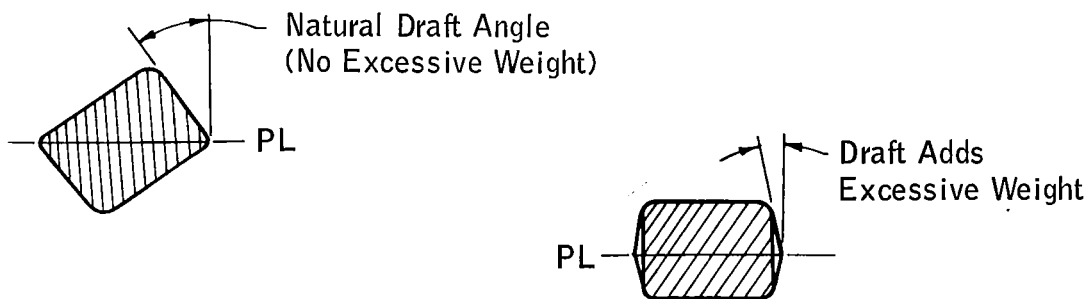
- b. When normal draft angles would not match at the parting line, the draft in the shallower die should be increased to match, or radiused to meet at the parting line.



- c. Radial draft results in the plan view when natural draft is used on circular sections. The end radius is drawn but is not dimensioned.



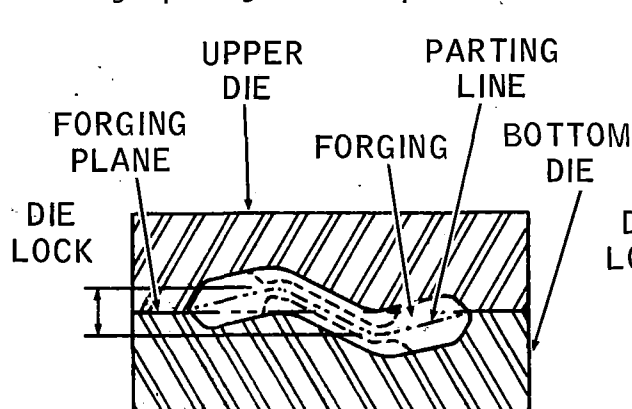
- d. Minimize weight and machining by taking advantage of natural draft angles.



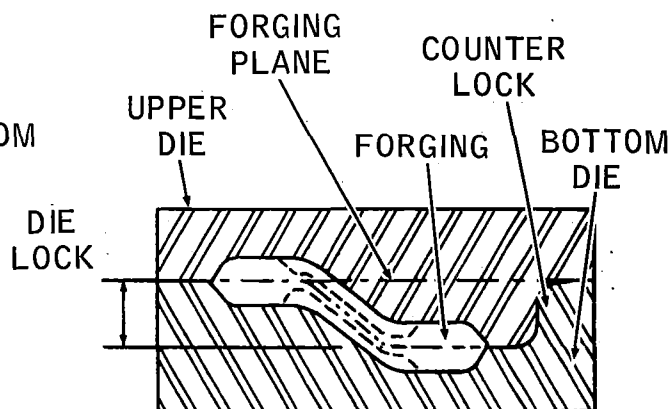
FORGINGS

27.2.1.5 Forging Plane

The forging plane is a horizontal plane normal to the stroke of the hammer. The forging should be positioned in the die to eliminate side thrust when other than a straight parting line is required.



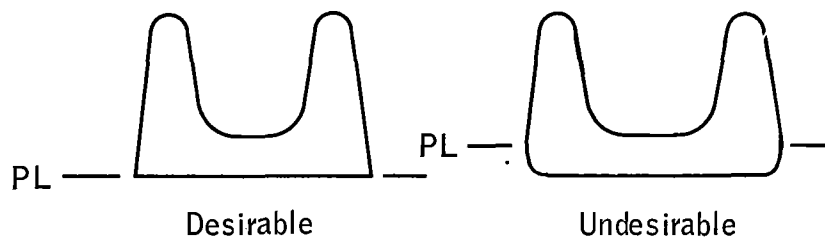
Preferred - The Best Method is to Incline the Forging With Respect to the Forging Plane.



Not Recommended - Dies with Counterlocks are Expensive to Build and Troublesome to Maintain

27.2.1.6 Parting Line

A parting line is a line around the periphery of the forging where the upper and lower dies meet. When possible, the parting line should be so located that one die half contains all the impression to shape the part. See illustration of channel section following.



When the parting line could be optional, it should be so stated and the most reasonable condition should be shown.

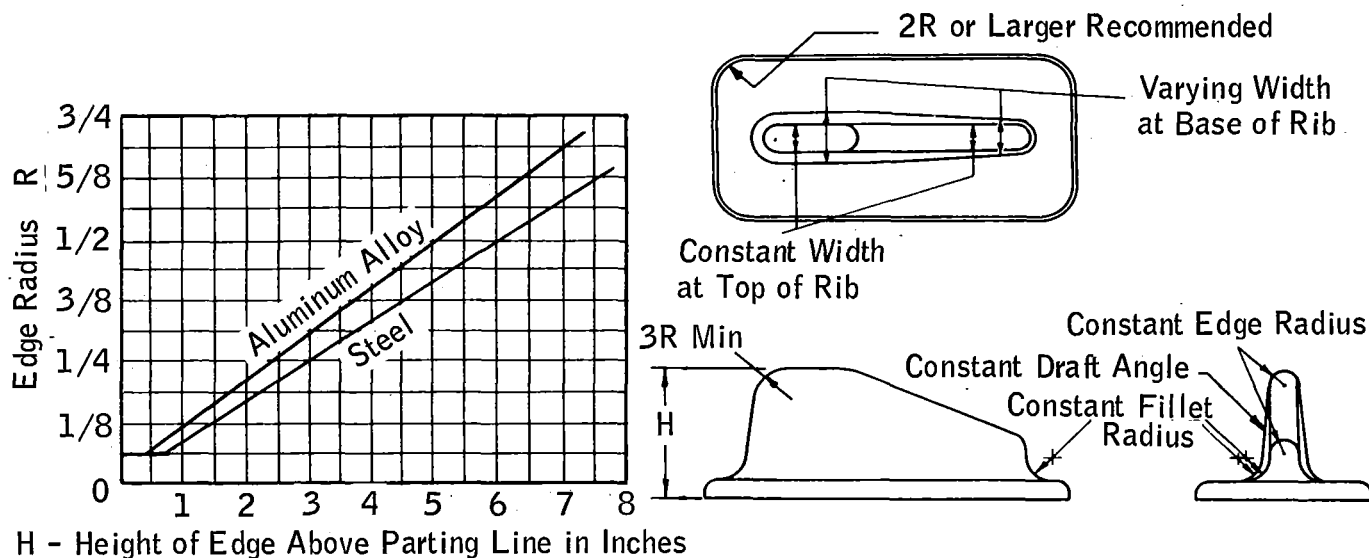
In order to facilitate die sinking and trimming, external webs less than 3/16 inch in thickness should have the parting line coincide with one surface of the web.



FORGINGS

27.2.1.7 Corner and Edge Radii

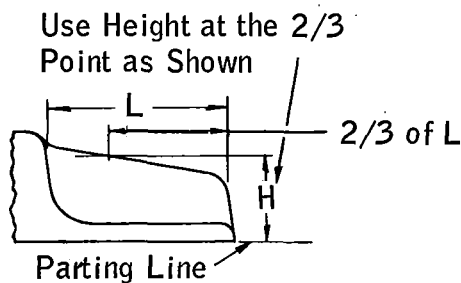
Corner and edge radii should not be smaller than the values shown.



Note: Keeping the draft angle, fillet radius, edge width and edge radius all constant along a rib with taper or varying height simplifies die sinking. Blending of different fillet radii should be done in localized corners.

27.2.1.8 Tapered Flanges

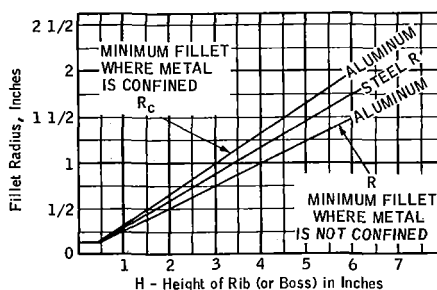
In order to save weight on long tapered flanges ending at heavier sections, use edge radius determined in 27.2.1.7 based on height of $2/3 L$.



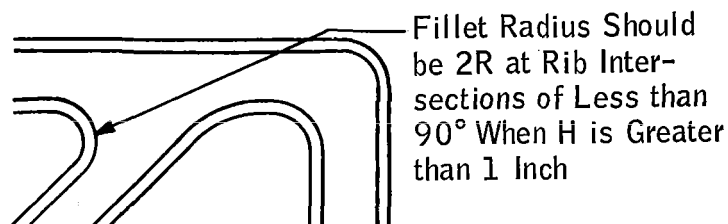
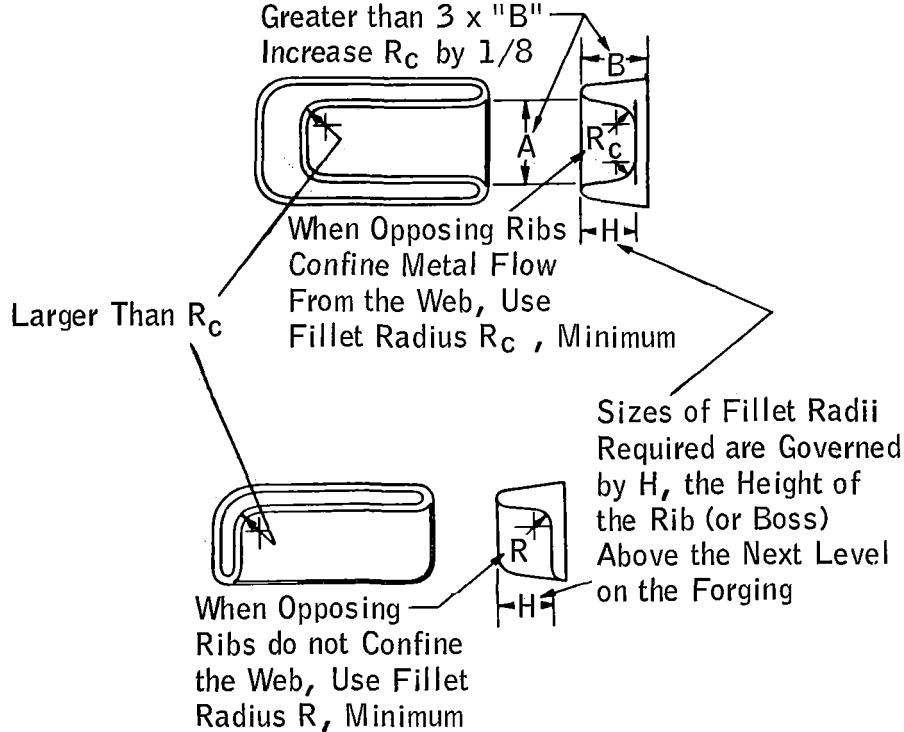
FORGINGS

27.2.1.9 Fillet Radii

Fillet radii on ribs and bosses should not be smaller than the values shown in chart.



Note: When "A" is Greater than 3 x "B" Increase R_c by $1/8$

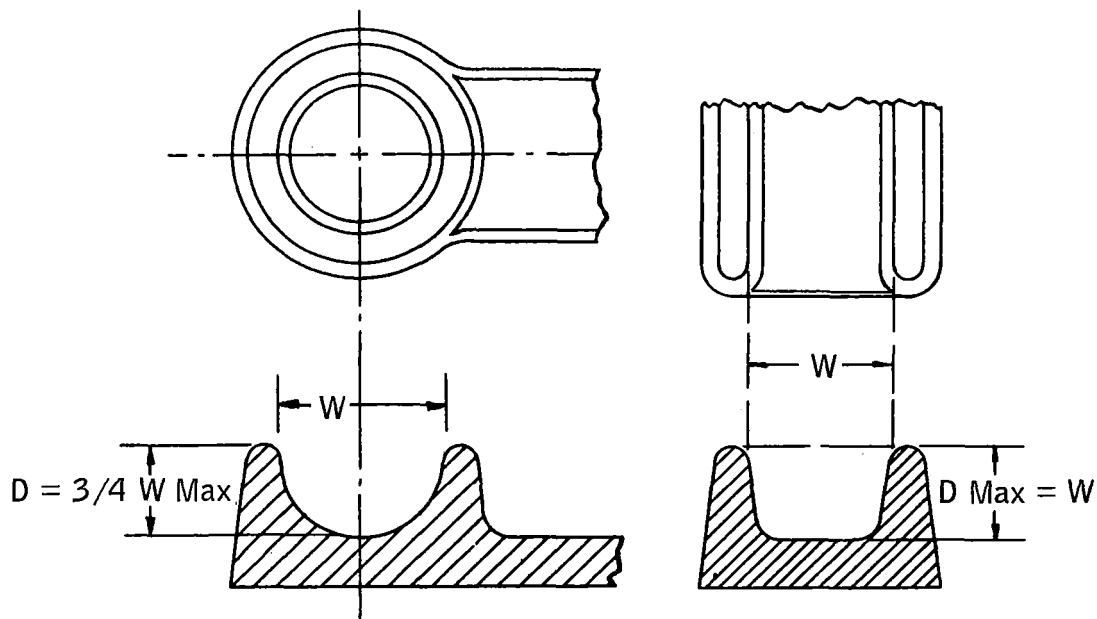




FORGINGS

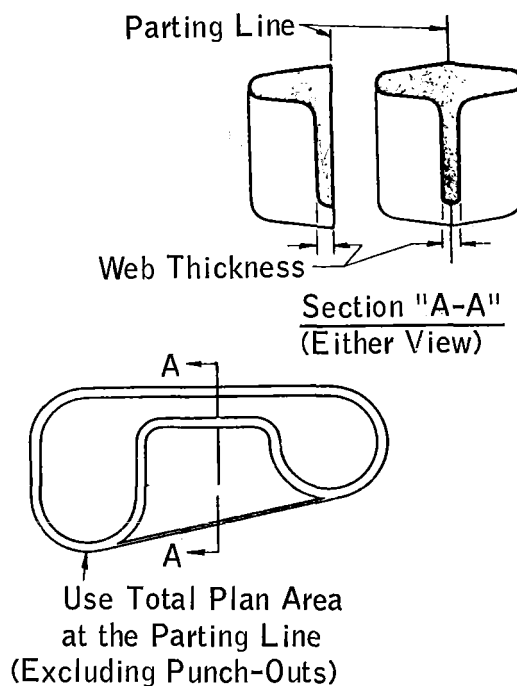
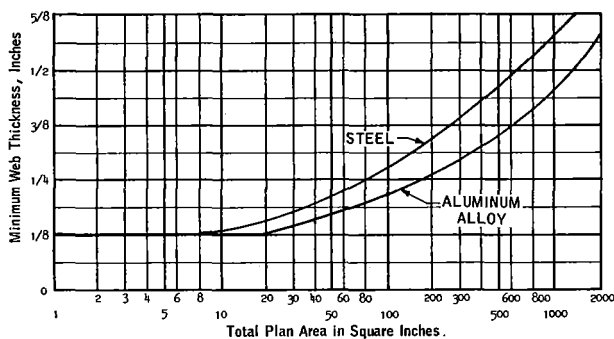
27.2.1.10 Cavities

Depth of round pockets shall not exceed $3/4$ of the width. For parallel ribs, the depth shall not exceed the width.



27.2.1.11 Web Thickness

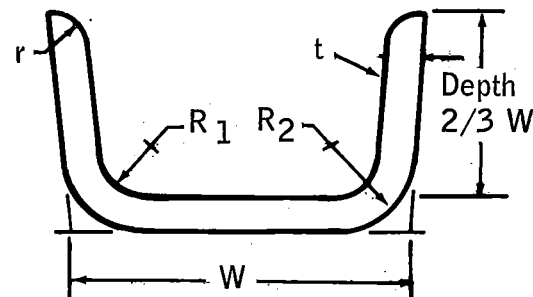
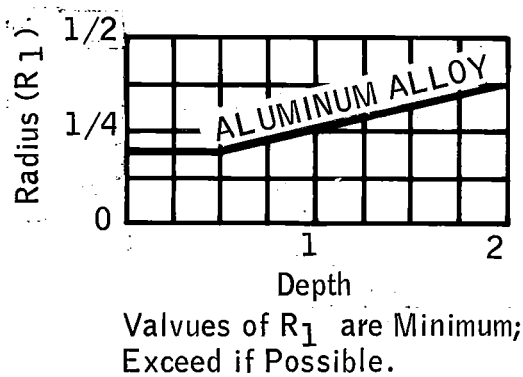
Webs of forgings should be at least as thick as the limiting proportions shown.



FORGINGS

27.2.1.12 Bathtub Forgings

Bathtub-type forgings, with the parting line at the rib edges, should follow the proportions shown.



$r = t$ (Recommended)
 $R_1 = \text{Chart Value}$
 $R_2 = R_1 + t$

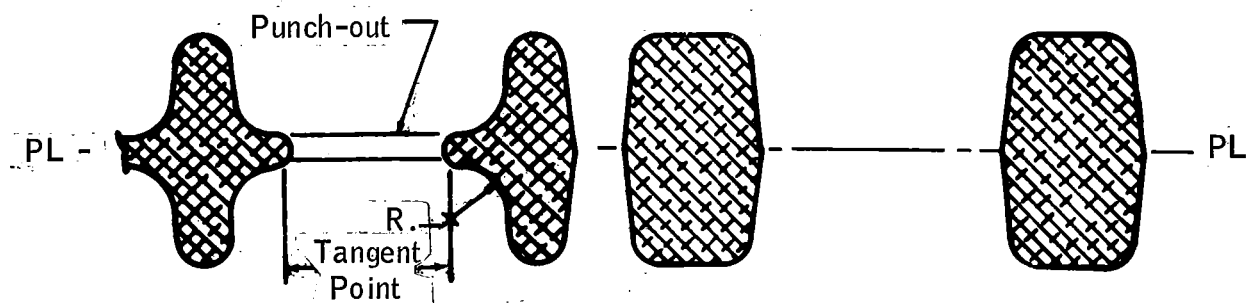
RECOMMENDED t	VALUE
$W =$	t
LESS THAN	
1 1/4	1/8
2	3/16
3	1/4
4	5/16

27.2.1.13 Punchouts

Punching is the cheapest method of obtaining a lightening hole in a forging and should be used whenever possible. Tolerance on punched-out hole location is $\pm 1/16$. In general, all punchouts should be only through the flat portion of the web as in Figure A. If the ribs are flat topped, other than round punchouts may extend to the draft intersection at parting line. See Figure B.

Figure A

Figure B



- Note:
1. Minimum punchout hole diameter 1
 2. Minimum punchout radius - - any shape hole 1/4
 3. Minimum spacing between round punchouts = 2 X web thickness.



 FORGINGS

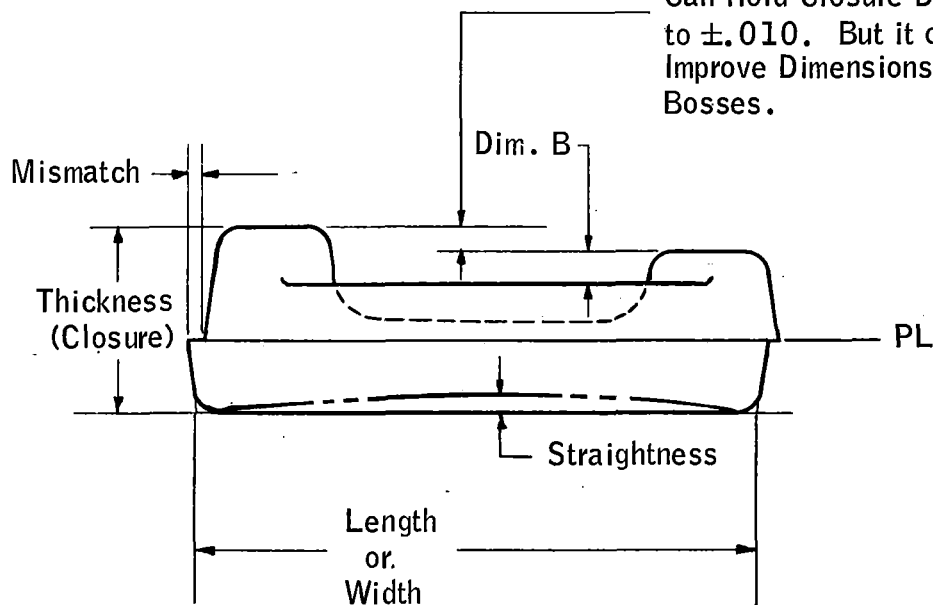
27.2.1.14 Tolerances

Tolerances given below are for steel and aluminum alloy. Where forging dimensions are critical (edge distance, machining, strength, etc.), the following tolerances should be considered.

- a. Length of part varies by mismatch, length and width tolerance.
- b. Thickness of part varies by closure and straightness.
- c. Width of part varies by mismatch, straightness, length and width tolerance.
- d. An extra $3/32$ minimum finish allowance, in addition to forging tolerances, must be added to any surface which is subsequently machined.

For Boss of 8 Sq. In. Max. Area

If Dimension B is $1/32$ or Greater the Coining Process Can Hold Closure Dimension to $\pm .010$. But it cannot Improve Dimensions Between Bosses.





Ground Support Equipment

FORGINGS

27.2.1.14 (Contd)

FORGING WT - LBS		THICKNESS (CLOSURE)				MAX MISMATCH		MAX FLASH EXTENSION	
		ALUMINUM ALLOY		STEEL					
FROM	UP TO	+	-	+	-	AL ALLOY	STEEL	AL ALLOY	STEEL
0	1	.016	.016	.032	.012	.016	.016	.016	.032
1	3	.032	.016	.032	.012	.032	.016	.032	.032
3	9	.032	.032	.032	.012	.032	.016	.062	.032
9	17	.045	.032	.039	.014	.032	.016	.062	.032
17	24	.062	.032	.042	.016	.032	.018	.093	.032
24	50	.093	.032	.057	.019	.045	FOR EACH ADD'L 6# ADD .002	.125	.062
50	100	.125	.045	.087	.029	.045		.125	.062
100	250			.125	.050				.062
250	UP			.180	.072				.062

Normal draft angle tolerance $\pm 1^\circ$.

Length and width tolerance, for dimensions up to 8 inches, $\pm .032$ $-.016$
 For each additional inch add $+.004$ $-.002$.

Straightness tolerance .016 per 9 inches.

27.2.1.15 Hole Allowances

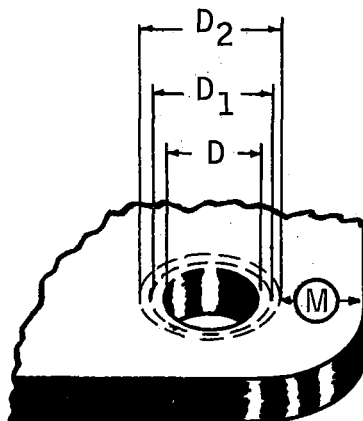
Forging designs should provide allowances for mislocation of holes. For fixed assemblies which are permanently fastened, allowance must be made for the next-higher size of bolts, rivets, and taper pins. For large-size bolts and taper pins, 1/16 oversize in diameter will be considered adequate. For bosses set far apart



27.2.1.15 (Contd)

and which are subsequently drilled or bored, oversize holes and forging tolerances may be allowed for by making one boss circular and elongating the other boss or bosses by an amount to cover these allowances, as illustrated below.

If assemblies consist of joints of connections that may be interchanged, allowances must be made for bolt or taper pin holes to provide for misalignment in any direction. This allowance shall be .06 on the diameter, plus an allowance for the next standard size bolt or pin. In terminals, an extra allowance of .06 shall be made for mislocation. Thus, an allowance of .19 on the hole diameter will cover both the possibility of hole misalignment and allowance for oversize bolts. The reduced edge margin or reduced area caused by the use of oversized bolts or pins shall be adequate to develop the required design strength of the part as illustrated.



D = Desired Hole Diameter

D₁ = D + .12 Allowance for Misalignment

D₂ = D₁ + .06 Allowance for Larger Bolt

(M) = Minimum Edge Margin

Hole Allowances

27.2.2 BLOCKER-TYPE FORGINGS

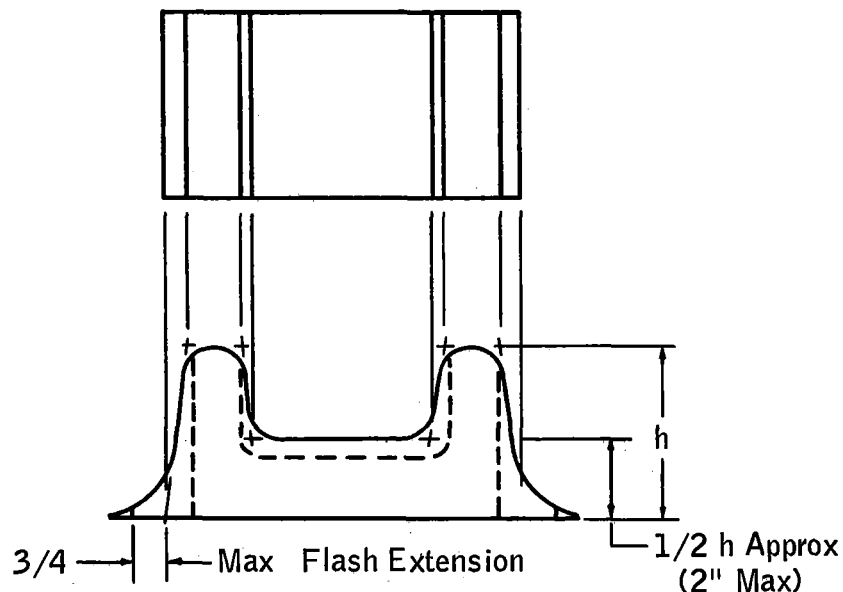
When all or most of the as-forged surfaces of a part will be machined, it may be possible to reduce the forging cost by as much as 50% by making the part easier to forge and thus decrease the number of forging dies required.

When designing a part for reduced die cost, the following shall be observed:

FORGINGS

27.2.2 (Contd)

- a. Thickness tolerances shall be approximately 20% greater than those described in Paragraph 27.2.1.14.
- b. Internal fillet radii shall be at least 25% greater than shown in Paragraph 27.2.1.9.
- c. Fillet radii at the flash line shall be very large. A radius shall be selected which will become tangent to the drafted surface at about half of the impression depth (up to 2" maximum for any depth). An average constant radius around the parting line is preferred. This large fillet is required to ease the flow of excess stock into the flash gutter.
- d. 3/4" maximum flash extension shall be allowed.



- e. Other proportions and tolerances shall be the same as described on preceding pages.

27.2.3 ROLLED-RING FORGINGS

Seamless rings can be produced by rolling a doughnut-shaped blank to desired dimensions. Generally, any material that can be wrought can be made into a ring by this method. Such rings are normally of rectangular cross section.



FORGINGS

27.2.3.1 Design Considerations

- a. For a large number of parts, consider rings formed from bar or extrusion, flash welded, then expanded to size (unless section size is too great for flash welding).
- b. Rolled-ring forgings may be obtained in a wide range of sizes from a minimum I.D. of 3 inches to a maximum of 24 feet. Wall thickness and length vary with the diameter and weight.
- c. It is possible to fabricate a ring with other than rectangular cross section; however, careful cost analysis should be made.
- d. Grain direction in rolled-ring forgings is circumferential. Other grain directions can be obtained by expensive forging methods but their use is restricted.

27.2.4 HAND FORGINGS

Hand forgings are made by forging bars or billets to approximate size and shape with open-type dies. They are used to advantage in the following applications.

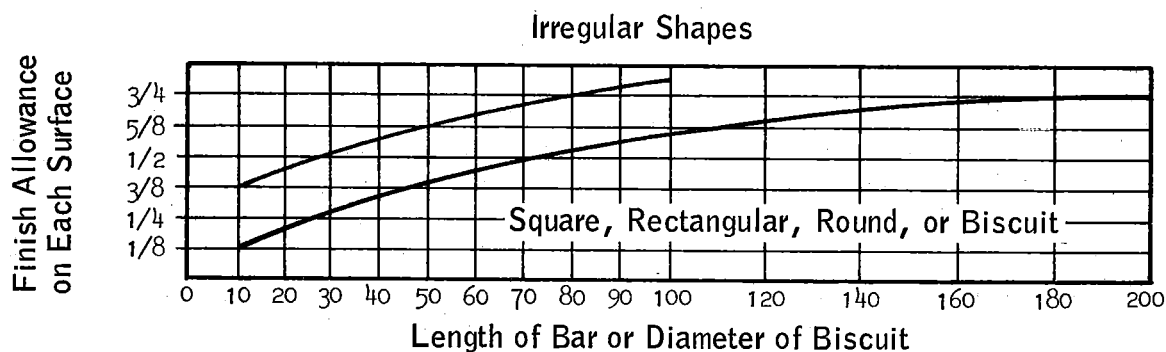
- a. When material is required for sections which must be made from larger than standard bar stock sizes.
- b. For steel parts requiring a raw stock sectional area greater than 20 square inches in which the core material is not subsequently removed.
- c. When an improvement in physical properties may be obtained by proper grain orientation, reduced section size in designated areas, or amount of working of the material.
- d. When the amount of material removed can be economically reduced by forging the approximate shape.
- e. When a limited number of parts is required which would normally be die forgings if sufficient quantity were required.

27.2.4.1 Finish Allowance

Excess material must be allowed on each surface of a hand forging so that 100% cleanup will result in machining each surface. This finish allowance must be determined and added to the required dimensions which enclose the desired part. It should be noted that cleanup only is considered and additional allowance must be made to provide for machining warpage.

FORGINGS

27.2.4.1 (Contd)



Note: Use nearest 1/32 to determine values.

27.2.4.2 Grain Orientation

Hand forgings have the best physical properties in the longitudinal grain direction, next best in the long transverse direction, and poorest in the short transverse direction. The short transverse property which shows the greatest fall off is elongation, and tests have shown that a reduction in fatigue and impact strength will result. Consequently, it is desirable to show the grain direction in the direction of maximum loading and to avoid designs which require high loads in the short transverse direction.

27.2.4.3 Amount of Work

Physical properties may be enhanced by increasing the amount of reduction performed in all directions. While it has not been possible to obtain hand forgings with a guaranteed amount of reduction, a requirement on the drawing that the material be forged in three directions should be imposed on critical parts.

27.3 PARTICULAR DRAWING PRACTICES

27.3.1 DELINEATION

Forged parts shall be delineated on monodetail drawings, except when existing conditions indicate that they should be delineated on a tabulated drawing or inseparable assembly drawing.



FORGINGS

27.3.1 (Contd)

Forging drawings, for parts requiring machining, are either prepared on separate drawings, one drawing for the part as forged and one for subsequent manufacturing operations required to complete the part, or are made as a single combination drawing.

Considerations, such as design requirements, incoming inspection of raw forgings, single or multiple source of supply for forgings, amount of machining required on the part, etc. shall dictate whether a single combination drawing or separate drawings for forging and machining will most effectively satisfy all requirements.

When the combination drawing is used, it may or may not (depending again on the considerations mentioned above) indicate draft angle, material to be allowed for finish machining, or grain flow, but it must contain directly, or by reference, all the necessary information to define the requirements of the finished article, such as material specification, heat treatment, finish, size, shape, etc.

When a separate delineation for the raw forging is used, it may be on a separate drawing or on the second sheet of a multisheet drawing. This drawing is made for the purpose of producing a forging from which the desired part may be made and shall contain only the information required for that purpose. It may or may not indicate material to be allowed for finish machining, but it must contain directly, or by reference, information such as material specification, draft angles, parting line, and, if important, grain flow.

The separate forging drawing shall include the following note above the title block in .18 inch minimum high letters:

"NOTICE: WHEN CHANGING THIS DRAWING, SEE
[MACHINING DRAWING NUMBER (S)]."

The separate machining drawing shall give all the information needed to machine and complete the part, but shall omit all dimensions of unmachined forged surfaces. The notation, "MAKE FROM (DIE NUMBER OF FORGING)," shall be included. The following note shall be placed above the title block in .18-inch minimum high letters:

"NOTICE: WHEN CHANGING THIS DRAWING, SEE
(FORGING DRAWING NUMBER)."

When sheet two of a multisheet drawing is used for forging delineation, sheet one shall include the following note above the title block in .18-inch minimum high letters:

"SEE SHEET TWO FOR FORGING REQUIREMENTS."

FORGINGS

27.3.1 (Contd)

In general, forging drawings follow standard drafting practices with a few exceptions to make them easier to interpret. For example: The plan view should show the draft by means of lines that would be used if the forging had sharp corners. (See Figure 1).

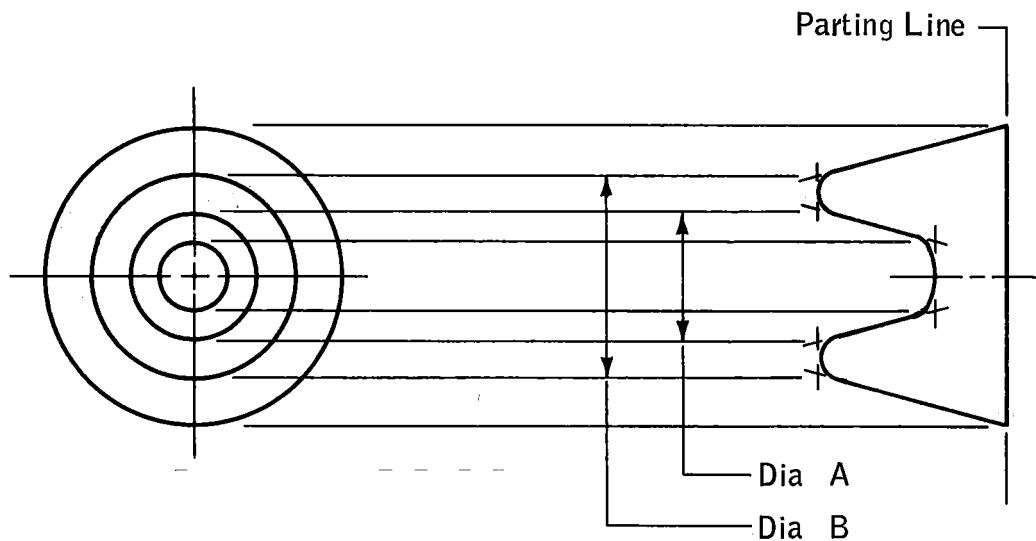
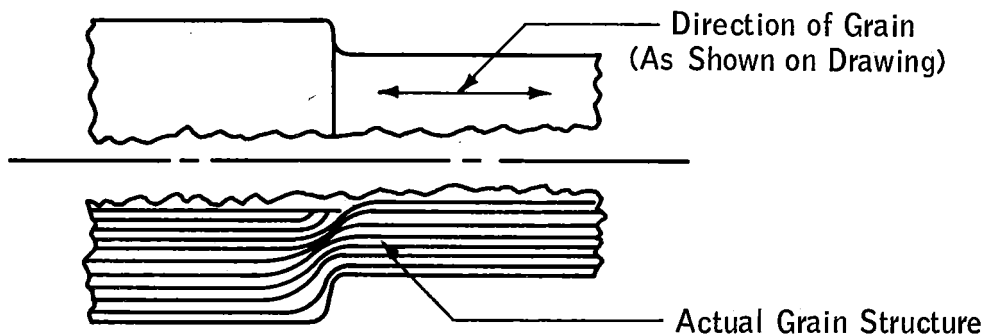


Figure 1

27.3.2 GRAIN DIRECTION OR FLOW LINES

When a definite grain direction is both desirable and determinable, it should be indicated on the forging detail drawing as shown below.



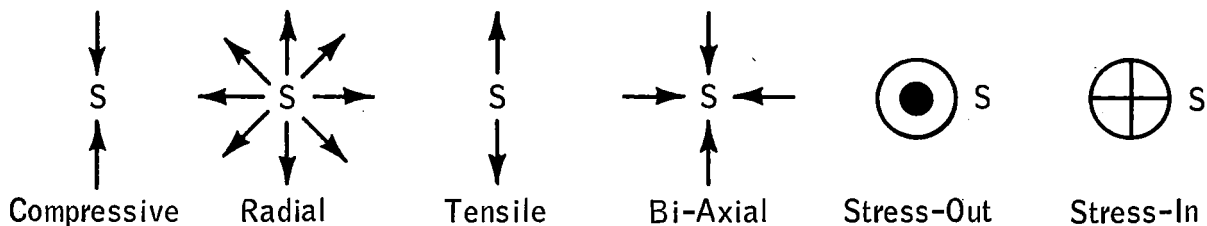


FORGINGS

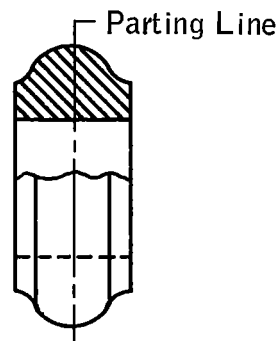
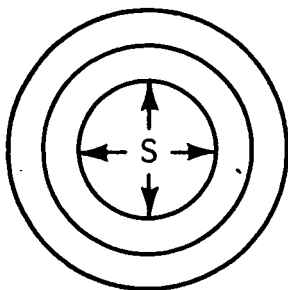
27.3.2.1 Stress Direction

When heavy stresses are encountered, particularly in complex forgings, the direction of grain is not always readily determined, in which case, the direction of stresses in the forging should be indicated on the forging detail drawing to assist in the design of the die that will produce acceptable forgings.

The direction of stresses may be indicated on the forging detail drawing (as illustrated below) by the following symbols:



Note: When using these symbols, a note explaining the symbols must appear on the drawing.

27.4 DIMENSIONING

When design permits, die forging dimensions parallel to the parting line should specify the feature size at the bottom of the die impression and allow the draft angle to determine the actual size at the parting line. Dimensions are normally taken from extended corners as shown in 27.3.1, Figure 1. In general, the basic principles of dimensioning castings, as outlined in 29.6 of this manual, may also be applied to die forgings.

27.5 IDENTIFICATION MARKING

Inspection stamps, serial numbers, vendor identification, heat treat, lot number, etc. should be located in a low stress and unmachined area of the forging and should be adjacent to the part number, if possible. The selected area should be a one inch minimum square, which is capable of being easily supported for stamping.



FORGINGS

27.5.1 COMMON IDENTIFICATION FOR RAW FORGING AND MACHINED PART

The part number should be located on a surface which will not be machined during a subsequent manufacturing operation. This shall be indicated by a note on the face of the drawing or by a symbol referring to a general note, such as "Forge XXMXXXXX-X on a surface not to be machined with characters .18 minimum high raised .02 \pm .01 from the surface."

27.5.2 DIFFERENT IDENTIFICATION FOR RAW FORGING AND MACHINED PART

In order to ensure controlled identification, different identification may be assigned to the raw forging and the machined part, even though a combined delineation is used. The raw forging will be identified by its die number, and the machined part by its drawing and part number.

Only the machined part shall be referenced on the next higher level assemblies.

27.5.2.1 Die Number

The die number consists of the drawing number and the addition of a suffix letter "H" and sequential numbers, such as "DIE XXMXXXXX-H1."

The forging shall carry the die number on a surface which will not be machined during a subsequent manufacturing operation. This shall be indicated by a note on the face of the drawing or by a symbol referring to a general note, such as "Forge XXMXXXXX-HX on a surface not to be machined with characters .18 min. high raised .02 \pm .01 from the surface."

27.5.2.2 Die References

Forging drawings shall specify the die identification near the part number, such as "DIE XXMXXXXX-HX" (Forged).

When a die change is made, the forging drawing referencing the die will reflect the change in the die number, such as H1, H2, H3, etc.

When a new forging can be produced using an existing die, the new drawing will be completely delineated and dimensioned and will include the material. The drawing will then reference the existing die number near the part number, such as "DIE XXMXXXXX-HX" (Forged).

FORGINGS

27.5.2.2 (Contd)

The raw forging will then be identified by the existing die number referenced on the drawing, and the finished machined part by its drawing and part number.

If, and when, a die change is required that is applicable to both the existing die and the new forging, both drawings must be updated to reflect the change.

If, and when, a die change is required that is not applicable to both the existing die and the new forging, the new forging drawing will be made the master die drawing by drawing a line through the reference to the existing die and adding its own die number, such as "~~DIE XXMXXXXX-HX~~" "DIE XXMXXXXX-H1" (die added).

When a new forging drawing references an existing die, both drawings should be cross referenced to each other by adding a note above the title block in .18 min. high letters, such as "NOTICE: WHEN CHANGING THIS DRAWING SEE [drawing number (s) involved]."

27.5.2.3 Die Number Change

The die number will be changed when a revision necessitates a change in the die, or when the material of the forging is changed. A die is considered to exist once the drawing is issued, and all subsequent die changes, including those made while the die is under construction, will require a die number change as outlined above.

All die changes must be recorded in the revision block of the forging detail drawing. The words "DIE CHANGE" must be added in the revision block of the drawing.

27.6 INSPECTION

Forgings are normally inspected for the following qualities (other than dimensional):

- a. Surface and subsurface defects (visual, liquid penetrant, and magnetic particle)
- b. Internal defects (microscopic and macroscopic)
- c. Mechanical properties (static destruction test of sample from forging lot)

The forging drawing shall state, either directly or via an inspection specification, the extent and frequency of inspection required and the acceptance standard for this inspection.



FORGINGS

27.7 NOTES**27.7.1 GENERAL**

When a single drawing for both forging and machining is used, notes shall be listed in two groups, those pertaining to the forging and those pertaining to other miscellaneous operations. The two groups of notes should be separated and headed to denote their use, "Forging Notes" and "Miscellaneous Notes." The forging notes should be numbered in blocks of ten or twenty, inclusive, as needed. For example, a combination forging and machining drawing with five forging notes and seven miscellaneous notes would list them as Forging Notes 1 through 5, Miscellaneous Notes 11 through 17.

27.7.2 SPECIFIC NOTES

For specific notes refer to section 9 of this manual.

EXTRUSIONS

28.1 GENERAL

The extrusion process is a means by which shapes of metals or plastics are produced by forcing metal, which is usually heated under high pressure, through an aperture of the shape to be produced.

28.2 GENERAL DESIGN INFORMATION

The purpose of this section is to present information to obtain the best design for an extrusion.

28.2.1 APPLICATIONS

- a. Where excessive or difficult machining is required to produce a desirable shape.
- b. When a more efficient use of metal is desirable than is obtainable with other methods of producing a shape.
- c. Where extrusions could replace small castings or forgings.

28.2.2 ADVANTAGES

- a. Metal or plastic material can be shaped into forms where a quantity of material is really needed.
- b. Extruding is cheaper than most other methods of forming shapes.
- c. The extrusion process produces shapes which are dense; surfaces are smooth and free of porosity.
- d. The dimensions of extruded shapes in most cases can be gauged with accuracy that they can be used directly with very little or no additional machining.
- e. Moderately short production runs are practical.

28.2.3 LIMITATIONS

- a. Dimensions are not as close as are possible in machining.
- b. Materials are limited to the more plastic metal.
- c. Size is limited to die and press limitations.

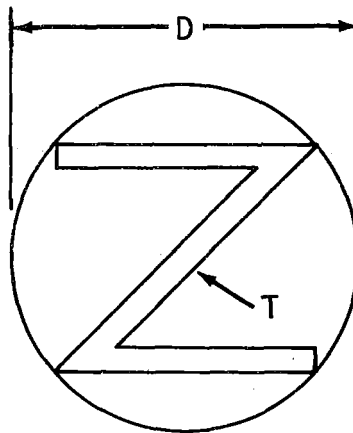


EXTRUSIONS

28.3 DESIGN DETAILS & MATERIALS

28.3.1 DESIGN DETAILS

- a. Thickness of extrusion sections should be proportionate to overall size. Average section thickness should be increased as the overall size increases. The minimum thickness extrudable depends upon the size of the section, determined by a circumscribing circle, as follows:



CIRCUMSCRIBING CIRCLE USED TO DETERMINE
MINIMUM THICKNESS IN EXTRUSION DESIGN

STANDARD MANUFACTURING LIMITS		
CIRCUMSCRIBING CIRCLE DIAMETER (D) INCHES	MINIMUM THICKNESS (T) INCH	REMARKS
Up to 1.99 incl	.050	These values are considered standard for 7075 material. Extrusions in softer material shall use these values unless quantities justify weight savings. These limits are applicable only to the average shape. Thickness greater than the standard minimum may be required for some shapes; less than standard minimum may be possible in others.
2.00 to 2.99 incl	.062	
3.00 to 3.99 incl	.078	
4.00 to 4.99 incl	.094	
5.00 to 5.99 incl	.109	
6.00 to 6.99 incl	.188	
7.00 to 7.99 incl	.219	
8.00 to 9.99 incl	.375	
10.00 to 12.99 incl	.437	
13.00 to 15.00 incl	.500	



Ground Support Equipment

EXTRUSIONS

28.3.1 (Contd)

- b. It is advisable to contact a Manufacturing Representative of extrusion products for detailed information in the design of extrusions.
- c. Extrusions should have uniform thickness and symmetry, thus allowing a uniform flow of metal. Extrusions that have nonuniform sections are difficult to extrude because metal flows easily in heavier sections and slowly in lighter sections.
- d. The length of a die projection or tongue, such as would be required in a channel section, is limited. Because tongues are unsupported and overhanging, they tend to bend or break during extrusion. Therefore, tongue length should be held within a maximum of four times tongue width.
- e. The radii on all corners shall be 0.016 minimum for thickness less than 0.125, and 0.031 minimum for thickness 0.125 and over.
- f. Extrusions should be designed so that they can be used in the as-received condition, without any rework.

28.3.1.1 Grain Direction

- a. Grain direction which develops during extrusion extends lengthwise with the direction of the extrusion. Tension perpendicular to the grain is avoided when possible.

28.3.2 DESIGN MATERIALS

28.3.2.1 Aluminum Alloy

- a. The principal aluminum alloys used for structural extruded shapes are numbers 7075 and 2024. Number 2024 should be used for large structural shapes which require maximum fatigue characteristics. Number 7075 should be used where maximum static properties are required.
- b. Several other alloys, such as 1100, 3003, 6053, and 6061 are available and should be used where high strength is not required and ease of forming is necessary.

28.3.2.2 Magnesium Alloy

- a. The principles of design outlined for aluminum alloys apply also to the design of extruded sections of magnesium alloy.



EXTRUSIONS

28.4 DIMENSIONING

- a. When dimensioning extrusions, consideration should be given to inspection as well as drafting practice. The use of unnecessary center lines for dimensioning should be avoided. Where possible, dimensions should be arranged so that measurements may be taken by caliper rule, micrometer, protractor, or similar standard tool. All dimensions should be given in decimals to three places.

CASTINGS

29.1 GENERAL

Castings are used to reduce or, in some cases, to eliminate machining and assembly costs. The various casting processes permit the production of simple or complex parts in one piece close to the final intended shape. They also afford the opportunity to obtain shapes possessing an extremely wide range of mechanical and metallurgical properties. These properties can be altered by heat treatment, local flame hardening, or by structure control during solidification.

29.2 ALLOY SELECTION**29.2.1 AIRBORNE APPLICATIONS**

Since weight is a prime factor, aluminum or magnesium alloys are usually used. Aluminum alloy castings are preferred to magnesium alloys for most airborne applications because of their greater resistance to corrosion, machinability, and lower cost. However, weight reduction often justifies the use of magnesium alloys. In some special cases, steel castings or other alloys may be used to meet certain requirements, such as magnetic, electrical, high stress, resistance to corrosion, etc.

29.2.2 NONAIRBORNE APPLICATIONS

In most nonairborne design, cost, not weight, is the deciding factor. In such designs, steel castings are usually used to advantage. When practical, low carbon steel and ductile iron castings are preferred to the alloy steels which are more difficult to cast and machine. Conditions may warrant the use of other alloys including aluminum and magnesium (see comments under airborne applications).

29.3 CASTING PROCESSES

The selection of the process to be used in casting a given part depends primarily on the tolerances that are required. Other factors, such as complexity, cost, size, material, delivery time, and quantities required, must also be considered before the "best possible" selection may be made.

The following general information is included here to aid in the design of cast parts that will have good producibility, and will perform their intended function satisfactorily at a reasonable cost. For unusual problems, or when in doubt as to the proper solution, a manufacturing and/or foundry representative should be consulted.



29.3 (Contd)

In general, green sand molding is the least precise, dry sand molding is next, followed by shell molds, permanent molds and investment molds in order of increasing accuracy. Generally speaking, the cost of patterns or tooling and the cost of castings made by these processes increase in the same order.

29.3.1 SAND CASTING

Sand casting is the most commonly used method of casting. Sand castings have low initial cost and permit flexibility in design changes during production. Sand casting is more suitable for producing a small number of pieces, or for making a moderate number that require fast delivery.

29.3.2 SHELL MOLD

Shell molding is most applicable to parts which are required in medium-to-high quantities. This method for producing castings offers minimum design limitations as to contours, small holes, sharp corners, and thin wall sections. A machined metal pattern is used to produce the mold, making possible better accuracy and surface finish.

29.3.3 PERMANENT MOLD

Permanent mold casting employs molds made from cast iron or steel. This process produces castings of high mechanical properties, good machinability, and very little internal porosity or shrinkage. Permanent molding does not lend itself to large or complex castings, nor to low production with short delivery time.

29.3.4 DIE CASTING

Die casting employs pressure to force the molten metal into the cavities in a steel die. Die casting gives low unit cost, and is ideal for the production of large numbers of thin-walled parts. Close tolerances and extremely smooth surfaces can be produced without subsequent machining and finishing.

29.3.5 INVESTMENT

In the investment process, a wax or plastic pattern is produced in a metal mold. This pattern is then surrounded with a ceramic material and the expendable pattern melted out. Metal cast into the cavity left by the wax or plastic pattern forms the final casting. The most significant feature of this process is the elimination of the parting line. The investment process is most advantageous in producing small intricate shapes, from difficult to machine alloys, and requiring close dimensional tolerances, and a fine surface finish.

CASTINGS

29.4 GENERAL DESIGN INFORMATION

29.4.1 PARTING LINE

Determination of the parting line of a casting is basically a foundry consideration; however, a possible parting method must be considered in design.

29.4.2 DRAFT

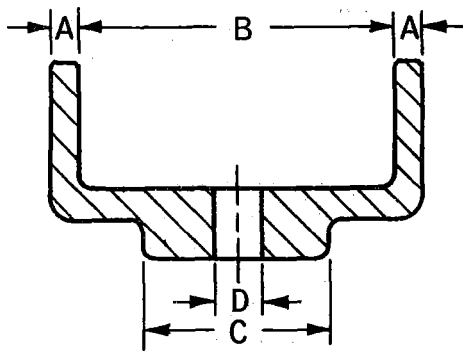


Figure 29-1

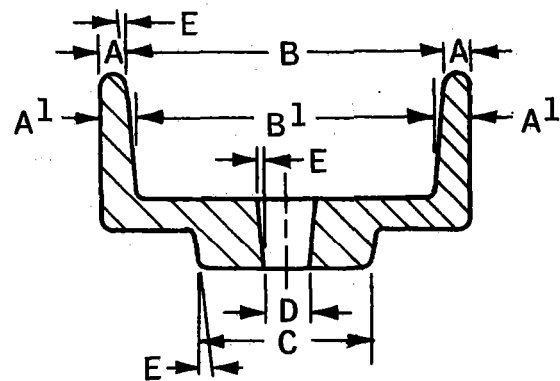


Figure 29-2

(AS SHOWN ON DWG.)

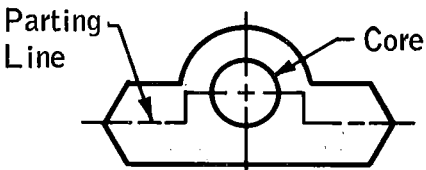
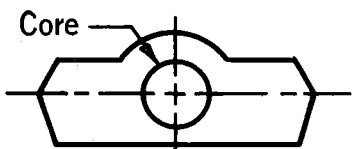
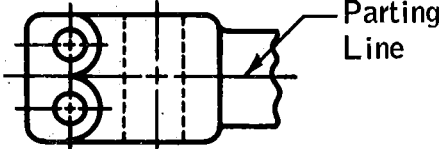
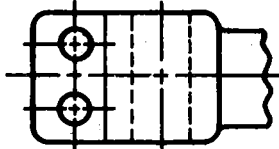

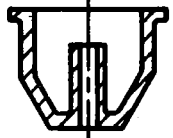
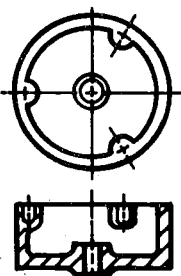
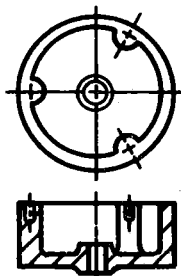
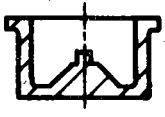
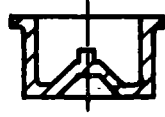
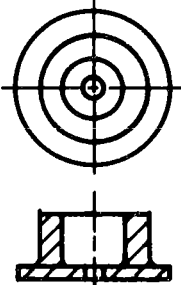
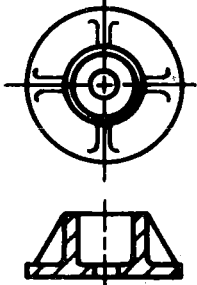
The dimensions shown for the thickness of walls, ribs, bosses, etc., apply before draft. Referring to Figure 29-2, the draft will be added to dimension "A" to give "A'" and subtracted from dimension "B" to give "B'". In no case shall the draft decrease the wall section "A" below tolerance for size. The diameter of cast holes (not machined) shall apply to the small end. Unless otherwise specified, the draft angle "E" may be 1° maximum for all types of castings except for permanent mold castings which require a draft of 2° maximum.



CASTINGS

29.4.3 DESIGN DETAIL CONSIDERATIONS

The purpose of this section is to present information and hints to obtain the best designs for castings.

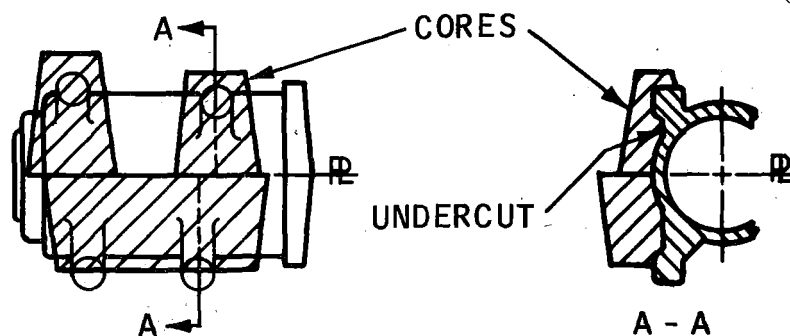
POOR DESIGN	IMPROVED DESIGN
<p>Parting lines should be as even or as straight as possible.</p> 	
	
	
	
	
	

CASTINGS

29.4.3 (Contd)

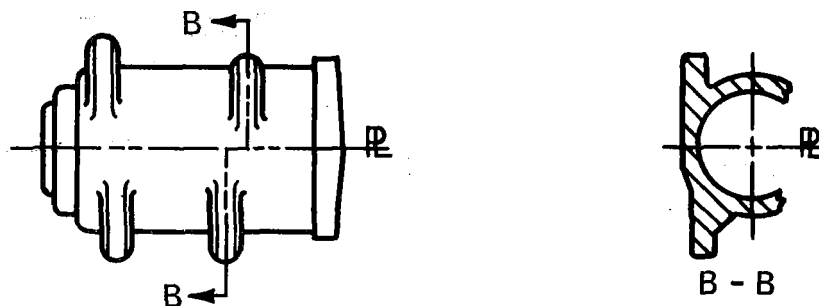
BOSS AND EAR DESIGNS

In general, locate bosses and ears on the parting line or extend the length of the boss to the parting line.



ORIGINAL DESIGN

Undercuts require cores as shown to permit removal of the pattern from the mold.



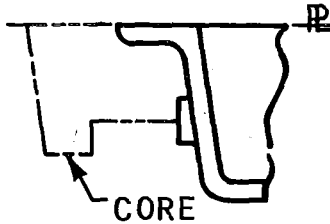
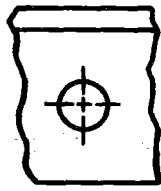
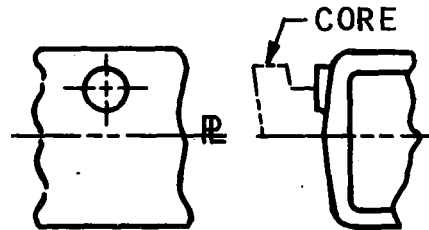
REDESIGN

The redesign eliminates the undercuts and eliminates the cores. Results are lower cost and more reliable casting due to elimination of any core mismatch.

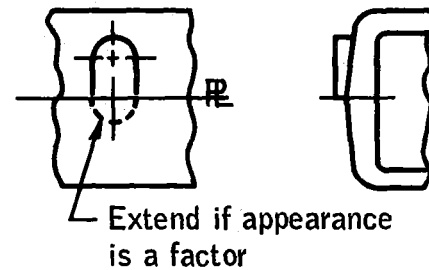
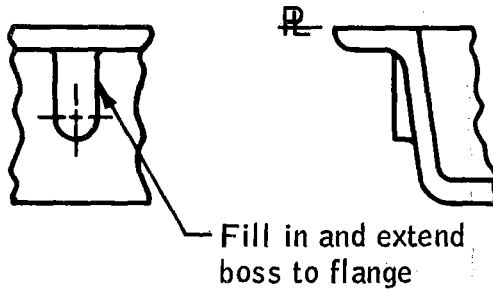


CASTINGS


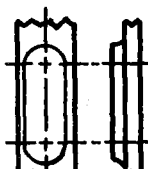
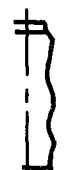
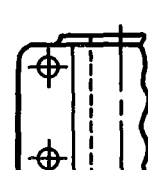

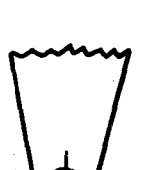
29.4.3 (Contd)

ORIGINAL DESIGNORIGINAL DESIGN

1 undercut created by a boss isolated from the parting line requires a core. Results are higher cost and possible core mismatch.



Extending the boss to the flange (or parting line) eliminates the core.

POOR DESIGN	IMPROVED DESIGN
 <p>Bosses on draft side cause difficult molding and often damage to mold.</p>	 <p>Solid elongated boss simplifies pattern and molding. If possible boss should be extended as shown above.</p>
 <p>More costly pattern and molding condition, avoid fanciful work.</p>	 <p>Simplified pattern and mold reduces cost.</p>
 <p>Difficult to withdraw pattern, no fillet.</p>	 <p>Produce flat surface by cold planishing or spot facing.</p>

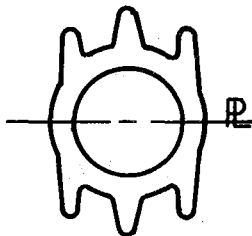
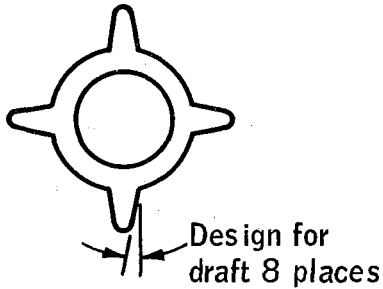
29.4.3 (Contd)

LONGITUDINAL RIBS ON CYLINDERS

BEST DESIGN

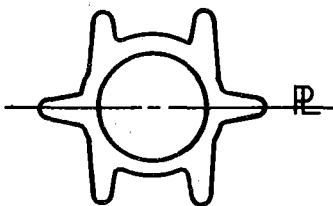
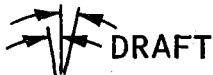
1, 2, 3 or 4 ribs on 90° centerline spacing

⌘ (parting line) on any centerline

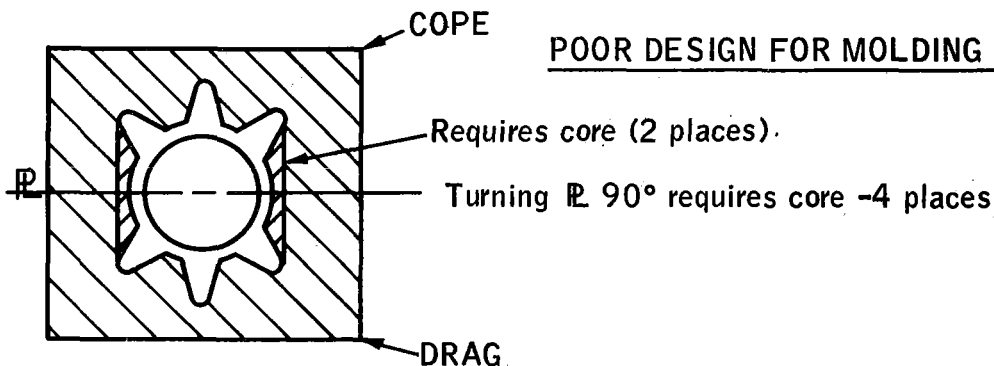


BEST DESIGN - When more than four ribs are required

All ribs perpendicular to one centerline



All ribs not on ⌘ are perpendicular to ribs on ⌘. Ribs on ⌘ are on centerline of cylinder



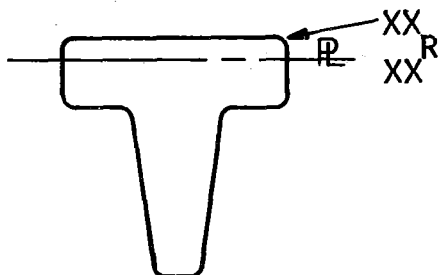
POOR DESIGN FOR MOLDING PRACTICE

CASTINGS

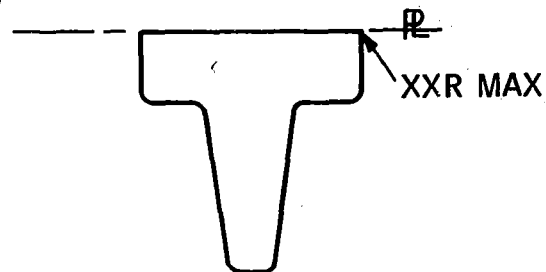
29.4.3 (Contd)

CORNER RADII

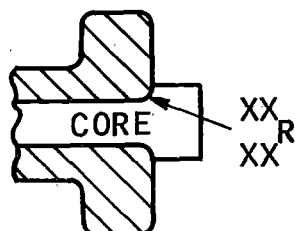
In general, specify cast corner radii - ".XX R MAX" prefer not to specify a tolerance band unless a minimum radius is functionally necessary.



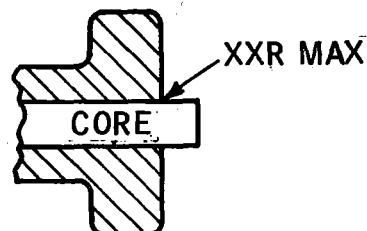
Requires split 2 - piece pattern - possible mismatch

PREFERRED

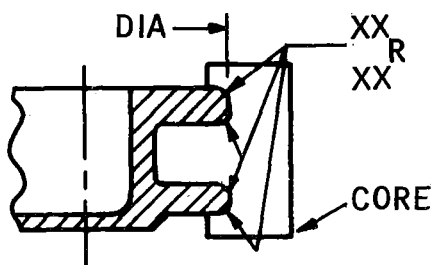
Requires simple 1 - piece pattern eliminating mismatch



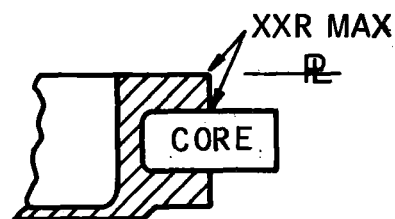
Requires special core design - possible mismatch

PREFERRED

Simple core eliminating mismatch, may be possible to use a stock core and eliminate cost of core box



Requires complex core box; special handling of the core during drying; special care during core setting in the mold. Outside dimensions are core controlled decreasing dimensional reliability; danger of mismatch.

PREFERRED

Simple core reducing cost and increasing reliability

CASTINGS

29.4.3 (Contd)

In general, it is best to specify all cast fillets with a maximum and minimum tolerance band on the radius, unless a relatively sharp corner is functionally necessary.

Avoid abrupt changes in cross section. Abrupt section changes are often stress-raisers in service, and are harder to cast than uniform webs, or blended section thickness changes. Blending is usually necessary when a thin section must be fed from a thick section that is not accessible to the gating system of the casting. When the thick section exceeds the thickness of the adjacent thin section by 50% or more (assume a machined surface to have 1/8-inch finish allowance), blending will be required. Some typical blended section changes are shown in the following illustrations.

STEEL

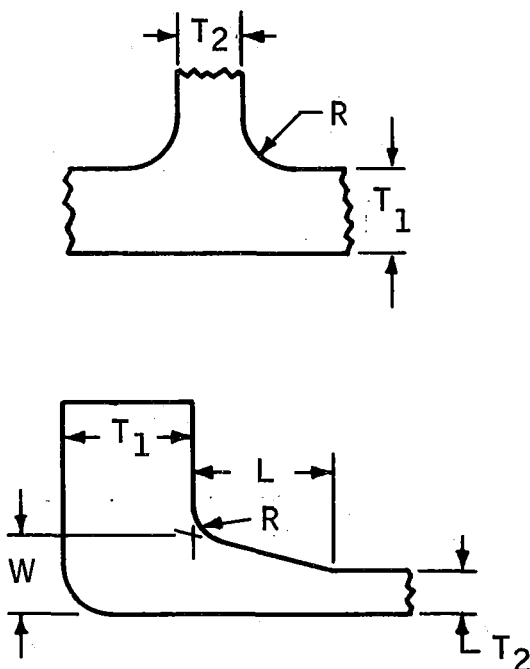
LEGEND: $>$ = greater than;

$<$ = less than

The recommended radius is dependent upon the heavier section T_1

When $T_1/T_2 \leq 2$

T_1	R
0 to 1/2"	Equal to T_1
1/2 to 1"	3/4 T_1
1" & up	1/2 T_1

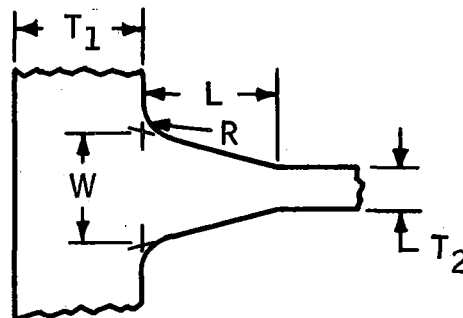


When T_1/T_2 is between 2 & 4

$$W = .75T_1$$

$$L = 1 - 1/2 T_1$$

$$R = .5T_2 \text{ (.019 MIN)}$$



When $T_1/T_2 > 4$

$$W = .75T_1$$

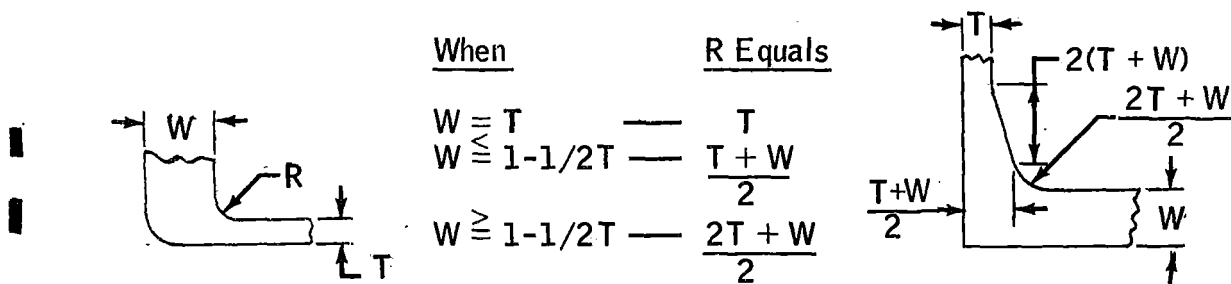
$$L = 2 T_1$$

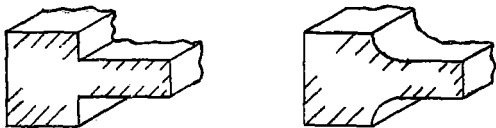


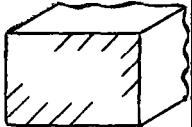
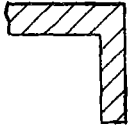

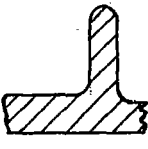
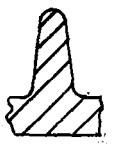
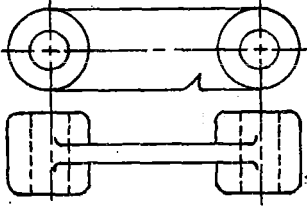
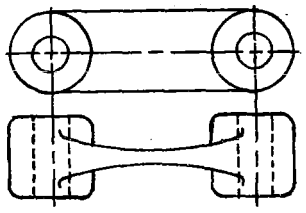
$$R = .5T_2 \text{ (.019 MIN)}$$

29.4.3 (Contd)

ALUMINUM AND MAGNESIUM

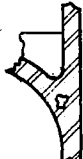


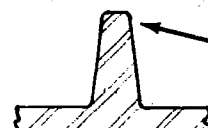
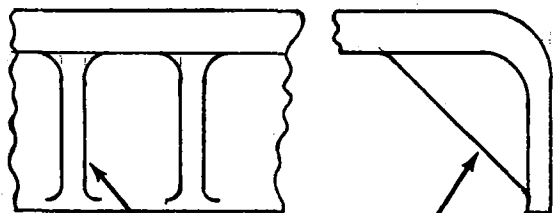
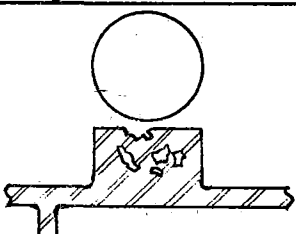

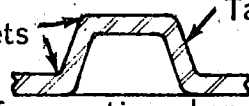




In general, for joints of equal sections, the radius should be equal to the thickness. For joints of unequal section, when the larger section is not more than 1-1/2 times the thin section, the radius should be the mean of the two sections. When the larger section is greater than 1-1/2 times the thin section, the radius should equal $\frac{2T + W}{2}$ and the fillet further extended by blending



POOR DESIGN		IMPROVED DESIGN		
		GOOD	BETTER	BEST
				 (NO CHANGE)
	Sharp corners and unequal wall thicknesses cause shrink holes and cracks		Rounded corners and more uniform wall thicknesses result in better cooling without cracks and shrink holes.	
	Shrinkage cracks are caused by unequal wall thicknesses or unequal sections when these are not relieved by sufficient fillets. No taper causes molding difficulties.		Large fillets and gradual change of sections prevent cracks. Taper facilitates removal of pattern and gives a smoother surface and more accurate casting.	
	Severe unequalness of sections & sharp fillets result in shrink holes and cracks.		Gradual change of sections & elimination of sharp fillets causes easier molding, more uniform contraction, & results in better castings.	

CASTINGS

29.4.3 (Contd)

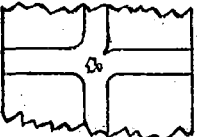
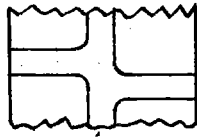
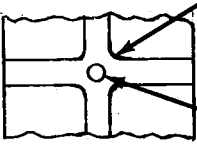
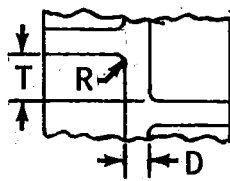
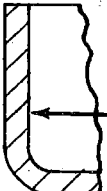
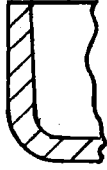
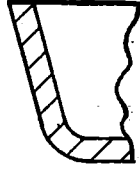
POOR DESIGN		IMPROVED DESIGN	
	Unequal sections frequently cause porous castings; would require proper feeding.		More equal sections result in more solid castings, but would require outside core. However, outside cores should be avoided wherever possible.
	High fiber or localized stresses on extreme outer edge may cause cracks.		More satisfactory fiber stresses.
<p>Where it is necessary to vary from light to heavy section, a gradual taper of the joints results in greater economy in production and in greater strength. If this is impracticable, ribs of sufficient thickness to allow feeding may be placed on the light sections so as to connect with, and feed into, a heavy section or boss.</p>		 <p>Ribs added to allow feeding</p>	
<p>Adjacent thin and thick sections cause porosity or shrinkage cavities when cooling. This requires chilling, heavy risers, or shrink heads which increase both molding and machining difficulties.</p>			
	To be avoided due to erosive action of molten metal especially on thin tongues and sharp fillets causing misforms, protuberances, and sand holes.	 <p>Larger Fillets</p> <p>Taper</p> <p>Core if possible</p> <p>More uniform section by reducing boss size.</p>	
		 <p>Large Fillets</p> <p>Taper</p> <p>More uniform section when employing a core and providing a boss with more sound metal.</p>	
	Unequalness of section causes porosity.		Cored, producing more uniform cross section of pad in relation to body.
			



CASTINGS

29.4.3 (Contd)

Concentration of mass at intersections of ribs and corners causes formation of shrinkage cavities and cooling stresses.

POOR DESIGN		IMPROVED DESIGN	
<p>VERY POOR</p>  <p>Rib intersection faulty due to too liberal fillets, causing increase in mass and cooling difficulties.</p>	<p>POOR</p>  <p>Offsetting arms a small amount does not improve the design</p>	<p>BETTER</p>  <p>Coring to equalize mass aids molding but adds to manufacturing costs.</p>	<p>slightly reduced fillets</p> <p>Cored hole</p> <p>BEST</p>  <p>Staggered ribs aids molding. For best design $T > 2D$ $R = 1 \text{ inch max}$</p>
 <p>No draft or taper</p>		  <p>Taper or draft aids in removal of pattern and causes less dislodgement of sand.</p> <p>If a circular section, design on right is best. If a channel, either design is equally good.</p>	

29.4.4 INSERTS

Studs, pins, electrical heating elements, tubing, etc. can often be cast in place as an integral part of the casting. Alignment is most accurate when the insert extends through the casting, so that both ends may be anchored in the mold or die. Cast-in-tubes can sometimes be used to produce curved holes, or to eliminate cores. All such inserts in dissimilar metals shall be cadmium or nickel-plated, and the subsequent protective finish processing for the casting itself shall consider the effect of the presence of dissimilar metals.

29.4.5 MINIMUM WALL THICKNESS

This data should be used for general guidance only. Actual design conditions will affect possible minima or maxima.

CASTINGS

29.4.5 (Contd)

The minimum wall section that can be cast with different alloys and by different processes is not absolutely fixed. (Aluminum-silicon alloys, for instance, will cast in thinner sections than aluminum-copper alloys.) It depends on the size and design of the casting, location of the section with reference to heavier adjacent sections, on the die, the alloy, the type of machine and the pressure applied. In general, the lower the melting point and the more fluid the metal, the shorter the distance the metal must flow between the chilling walls of the die or mold, or the faster it traverses the distance, the thinner the wall may be. There is practically no limitation on casting heavy wall thicknesses as may be encountered in commercial applications. Sections somewhat heavier than minimum castable are recommended (especially for die and pressure castings) when castings are to be plated, as they hold greater promise for smooth surface.

MINIMUM WALL THICKNESS (INCH)					
MATERIAL	CASTING PROCESS				
	SAND	PERMANENT MOLD	DIE	SHELL	INVESTMENT
Steel	See Fig. 1	—	—	.16 under 3 in. .19 3 to 6 in. .22 6 to 12 in.	.05 min. .09 preferred
Aluminum Alloy	.12 under 3 in. .16 3 to 6 in. .19 over 6 in.	.10 under 3 in. .12 3 to 6 in. .16 over 6 in.	.05 SM CSTG .08 LG CSTG	.06 under .5 in. .09 .5 to 3 in. .12 3 to 6 in. .16 over 6 in.	.08 under 3 in. .10 over 3 in.
Magnesium Alloy	.16 SM CSTG	.09 under 2 in. .12 2 to 4 in. .16 4 to 6 in. .19 over 6 in.	.06 SM CSTG .09 LG CSTG	—	—
Cast Iron	.12 min .25 preferred	.08 min .12 preferred	—	.06 SM CSTG	.05 min .09 preferred
Brass and Bronze	.09 Brass .12 Bronze	.08 SM CSTG	.06 SM CSTG .12 LG CSTG	.06 SM CSTG	.03 min .08 preferred



CASTINGS

29.4.5 (Contd)

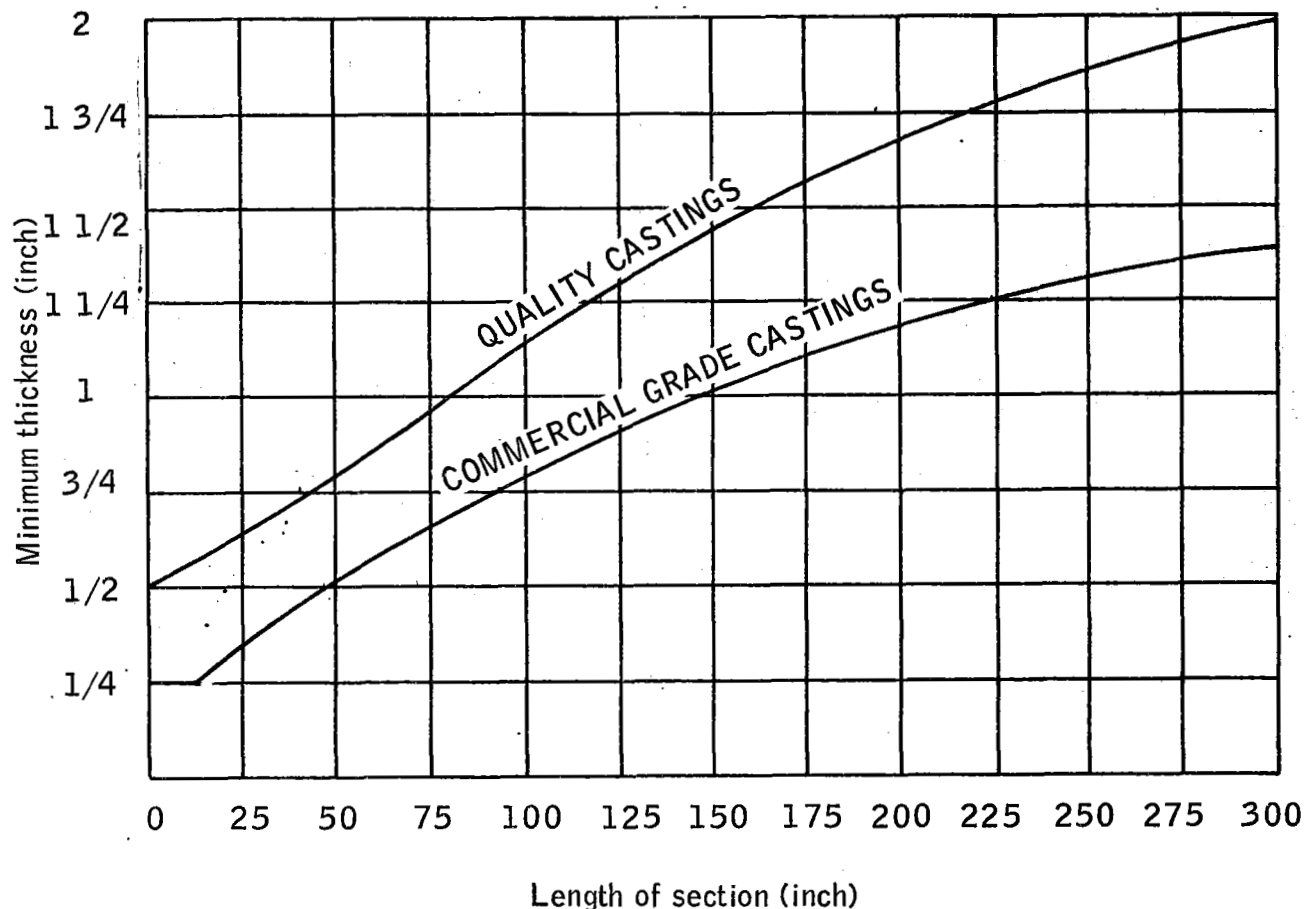


Fig. 29-3 Minimum Thickness of Cast-Steel Sections
as a Function of Their Largest Dimension

Note: Thin sections in large rangy castings are subject to extremely high stresses during cooling, which very often result in hot tears or cracking. These small cracks are generally acceptable in commercial grade castings. For quality castings, use the thicker sections.

29.4.6 TOLERANCES

This data should be used for general guidance only.

The tolerances given here are meant to indicate the normal tolerances that may be expected from the principal molding processes under general conditions. Many factors affect the dimensional accuracy of a casting; therefore, under certain conditions, tolerances can be held closer than those shown, and occasionally the opposite may occur. To permit maximum value at minimum cost, specify tolerances actually needed; do not ask for closer tolerances than necessary, but do not hesitate to ask for what you really need. In grey areas, consult a foundry representative.

CASTINGS

29.4.6 (Contd)

LINEAR TOLERANCES						
		CASTING PROCESS				
		SAND	PERMANENT MOLD	DIE	SHELL	INVESTMENT
ALUMINUM AND MAGNESIUM	General Tolerance	$\pm .006"/in.$ or $\pm .030"$ whichever is greater	$\pm .003"/in.$ or $\pm .020"$ whichever is greater	$\pm .0015"/in.$ or $\pm .010"$ whichever is greater	$\pm .005"/in.$ or $\pm .015"$ whichever is greater	$\pm .005"/in.$ or $\pm .015"$ whichever is greater
	See Note	$\pm .030"$ up to 24" $\pm .003"/in.$ over 24"	$\pm .0015"/in.$ or $\pm .015"$ whichever is greater	$\pm .0015"/in.$ or $\pm .003"$ whichever is greater	_____	Up to .25" $\pm .003"$.25" to .50" $\pm .004"$.50" to 1.00" $\pm .005"$ over 1.00" $\pm .005"/in.$
STEEL	General Tolerance	$\pm .012"/in.$ or $\pm .060"$ whichever is greater	_____	_____	$\pm .008"/in.$ or $\pm .030"$ whichever is greater	(To 50#) $\pm .005"/in.$ or $\pm .015"$ whichever is greater
	See Note	$\pm .030"$ up to 5" over 5" use gen. tol.	_____	_____	_____	Up to .25" $\pm .003"$.25" to .50" $\pm .004"$.50" to 1.00" $\pm .005"$ over 1.00" $\pm .005"/in.$
CAST IRON BRASS AND BRONZE	General Tolerance	$\pm .006"/in.$ or $\pm .030"$ whichever is greater	$\pm .004"/in.$ or $\pm .020"$ whichever is greater	Brass and Bronze only $\pm .003"/in.$ or $\pm .010"$ whichever is greater	_____	$\pm .005"/in.$ or $\pm .015"$ whichever is greater
	See Note	$\pm .030"$ up to 24" $\pm .003"/in.$ over 24"	$\pm .004"/in.$ or $\pm .010"$ whichever is greater	Brass and Bronze only $\pm .003"/in.$ or $\pm .005"$ whichever is greater	_____	Up to .25" $\pm .003"$.25" to .50" $\pm .004"$.50" to 1.00" $\pm .005"$ over 1.00" $\pm .005"/in.$
Angular		$\pm 2^\circ$	$\pm 1^\circ$	$\pm 1/2^\circ$	$\pm 1^\circ$	$\pm 1/2^\circ$

NOTE: These tolerances to be specified only when functionally necessary and when specified are subject to vendor approval; generally require foundry development - this means time and money.

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CASTINGS

29.4.7 NORMAL MATERIAL ALLOWANCE FOR MACHINE SURFACES

Casting Dimension	Aluminum	Magnesium	Steel/Malleable Iron
Under 12 inches	3/32	3/32	1/4
12" to 34 Incl	1/8	1/8	5/16
Over 34" to 48 Incl	1/4	1/4	3/8
Over 48" to 72 Incl	3/8	3/8	1/2
<u>Bores</u>			
Up to 1" Incl	1/8	1/8	Cast Solid
Over 1" to 7 Incl	3/16	3/16	1/4
Over 7" to 12 Incl	1/4	1/4	3/8
Over 12" to 20 Incl	3/8	3/8	1/2"

29.4.8 CAST FINISHES

NORMAL					
	Sand	Permanent Mold	Die	Shell	Precision
Aluminum	500	250	125	250	125
Magnesium	500	250	125	250	125
Steel	2000	---	---	250	125
FINE					
Aluminum	250	← Same as Normal →			
Magnesium	250				
Steel	250				

29.4.9 TENSILE PROPERTIES & BRINELL HARDNESS OF ALUMINUM ALLOY CASTINGS

Alloy & Temper	TS (*)		YS (*)		Elongation %		Brinell	
	S	PM	S	PM	S	PM	S	PM
355 - T51	28	30	23	24	1.5	2	65	75
- T 6	35	43	25	27	3.0	4	80	90
- T 7	38	40	36	30	0.5	2	85	85
- T71	35	36	29	31	1.5	3	75	85
356 - T51	25	--	20	--	2.0	-	60	--
- T 6	33	40	24	27	3.5	5	70	90
- T 7	34	33	30	24	2.0	5	75	70
- T71	28	--	21	--	3.5	-	60	--
A356 - T 6	38	41	28	28	6.0	12	70	80

(*) No. given times 1000

S = Sand

PM = Permanent Mold

CASTINGS

29.4.10 AVERAGE PATTERN LIFE FOR SAND CASTINGS

TYPE OF PATTERN			
CHEAP PINE	MAHOGANY	METAL-FACED	METAL
25	100	200	5000

29.4.11 AVERAGE MOLD OR DIE LIFE

MATERIAL	CASTING PROCESS			
	PERMANENT MOLD	INVESTMENT		DIE CAST
		SOFT METAL	STEEL	
Steel	-----	10,000	150,000	-----
Cast Iron	10,000	10,000	150,000	-----
Copper Base Alloy	10,000	10,000	150,000	50,000
Aluminum Alloy	100,000	10,000	150,000	150,000
Magnesium Alloy	100,000	10,000	150,000	150,000

29.4.12 ECONOMICAL QUANTITIES

MATERIAL	CASTING PROCESS				
	SAND	PERM. MOLD	SHELL	INVESTMENT	DIE
Ferrous and Nonferrous Alloys	Wood Equipment 1 to 100	500 to 3000	25 to 500	Soft Metal Mold 50	3000 to 5000
	Metal Equipment 100 to 1000			Steel Mold 500	

29.5 PARTICULAR DRAWING PRACTICES

29.5.1 DELINEATION

Cast parts shall be delineated on monodetail drawings except when conditions indicate they should be delineated on a tabulated drawing, or inseparable assembly drawing.

SECTION 29

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29.5.1 (Contd)

Casting delineation shall not show draft angle, or amount of material to be provided for the finish of machined surfaces unless it is a design requirement, or other considerations make it advisable.

It is usually more economical to delineate castings as a combination machining and casting drawing. However, the raw casting may be delineated as a separate drawing, or on the second sheet of a multisheet drawing, when complexity of the part, increased clarity, or other benefits warrant it.

When the combination drawing is used, it shall contain all the information needed for producing the raw casting and machining it, as well as for applying protective coatings, inspection requirements, etc.

When the multisheet drawing, or a separate drawing is used, the raw casting drawing shall contain all the information needed to produce the raw casting, including inspection requirements, condition of cast surfaces, heat treatment, etc. The machining drawing shall give all the information needed to machine and complete the part, but shall omit all dimensions of unmachined cast surfaces.

The raw casting drawing shall include the following note above the title block in .18-inch minimum high letters:

"NOTICE: WHEN CHANGING THIS DRAWING, SEE
[MACHINING DRAWING NUMBER (S)]."

The machining drawing shall note in appropriate manner:

"MAKE FROM PATTERN (PATTERN NUMBER OF RAW CASTING)."

The machining drawing shall include the following note above the title block in .18-inch minimum high letters.

"NOTICE: WHEN CHANGING THIS DRAWING SEE
(RAW CASTING DRAWING NUMBER)."

When sheet two of a multisheet drawing is used for the raw casting delineation, sheet one shall include the following note above the title block in .18-inch minimum high letters.

"SEE SHEET TWO FOR CASTING REQUIREMENTS."

CASTINGS

29.6 **DIMENSIONING**

In general, castings shall be dimensioned from an established surface, or surfaces, from which each process starts. These surfaces are unmachined surfaces, selected for their strategic positions in molding, and other subsequent operations. Such surfaces designated as "base line" or a "datum plane" may be established by tooling points on that surface (see 29.6.1). The "base line" or "datum plane" will then be the starting point for all other dimensions in each plane, and will serve to position the casting for checking and machining.

The tolerance on a dimension between a cast surface and a machined surface is usually considered to be the same as the tolerance on a dimension between two cast surfaces; therefore, any subsequent machining, after the "first cut" in each plane, is normally dimensioned between related features, with the functional tolerances required.

29.6.1 **TOOLING POINTS AND TOOLING LOCATIONS**

The following data provides a guide for the interpretation and application of tooling points and tooling locations.

Tooling points and tooling locations are used to correlate manufacturing and inspection procedures with the functional requirements, dimensions, and tolerances of castings.

When the casting is on a separate drawing from the machining, the tooling points and/or tooling locations must also be shown and dimensioned on the machining drawing.

29.6.1.1 **Definitions**

- a. **Tooling Points** - Tooling points are defined fixed points on accessible surfaces used to locate the part in a predetermined position for inspection and machining. The tooling points determine, and are coincidental with, the datum planes from which measurements shall be taken in a direction perpendicular to the established datum planes. Tooling points that establish any one datum plane are located on the drawing at specified distances from the other two datum planes.
- b. **Tooling Locations** - Tooling locations are dimensioned points on accessible surfaces for dimensionally locating datum planes which are not coincident with tooling locations. Tooling locations are used only when datum planes, due to location, cannot be established by tooling points.

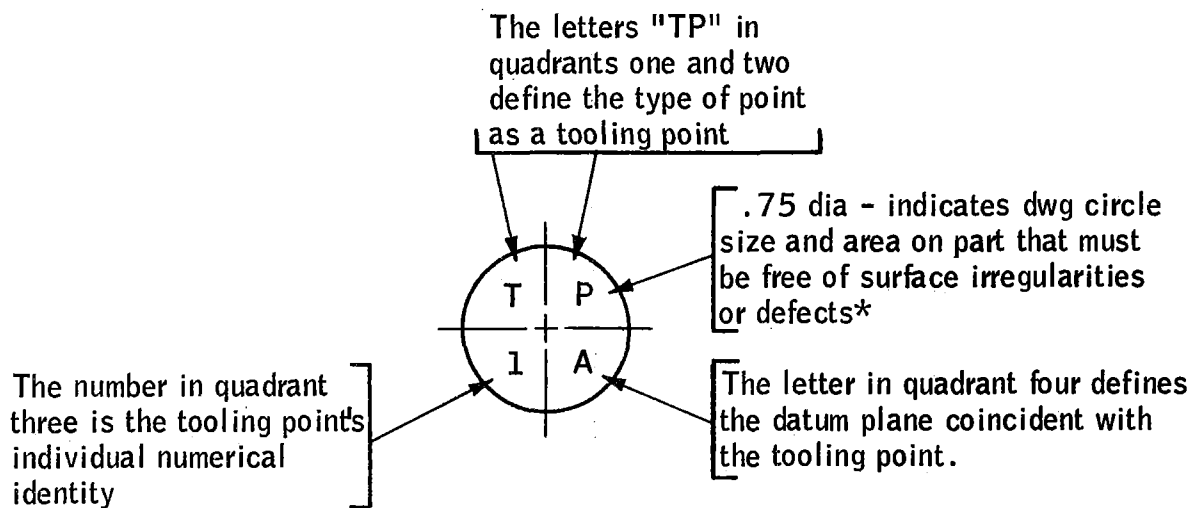
CASTINGS

29.6.1.1 (Contd)

- c. Datum Plane - A datum plane is a theoretically perfect plane which serves as the zero or starting plane for the dimensions that extend in a direction perpendicular to it. Datum planes shown intersecting at right angles shall have an implied angle of intersection of $90^\circ \pm 0^\circ$ (90° basic) even though no angle is specified. Methods of establishing datum planes are illustrated in Figures 29-4, 29-5, and 29-6.

29.6.1.2 Symbols

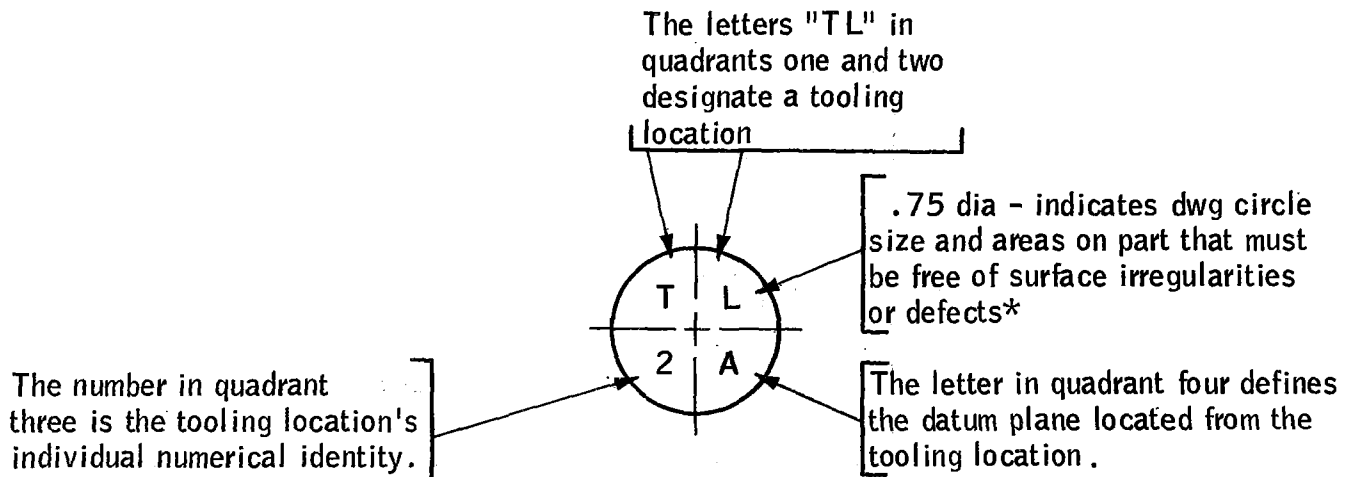
- a. Tooling Point Symbol - The following symbol shall be used to identify all tooling points:



- b. Tooling Location Symbol - The following symbol shall be used to identify all tooling locations:

CASTINGS

29.6.1.2 (Contd)



* .75 dia is desirable, but may be reduced by space limitations.

- c. Datum Plane Symbols - Datum planes shall be identified by standard datum identifying symbols per MIL-STD-8, e.g. - A - , etc.

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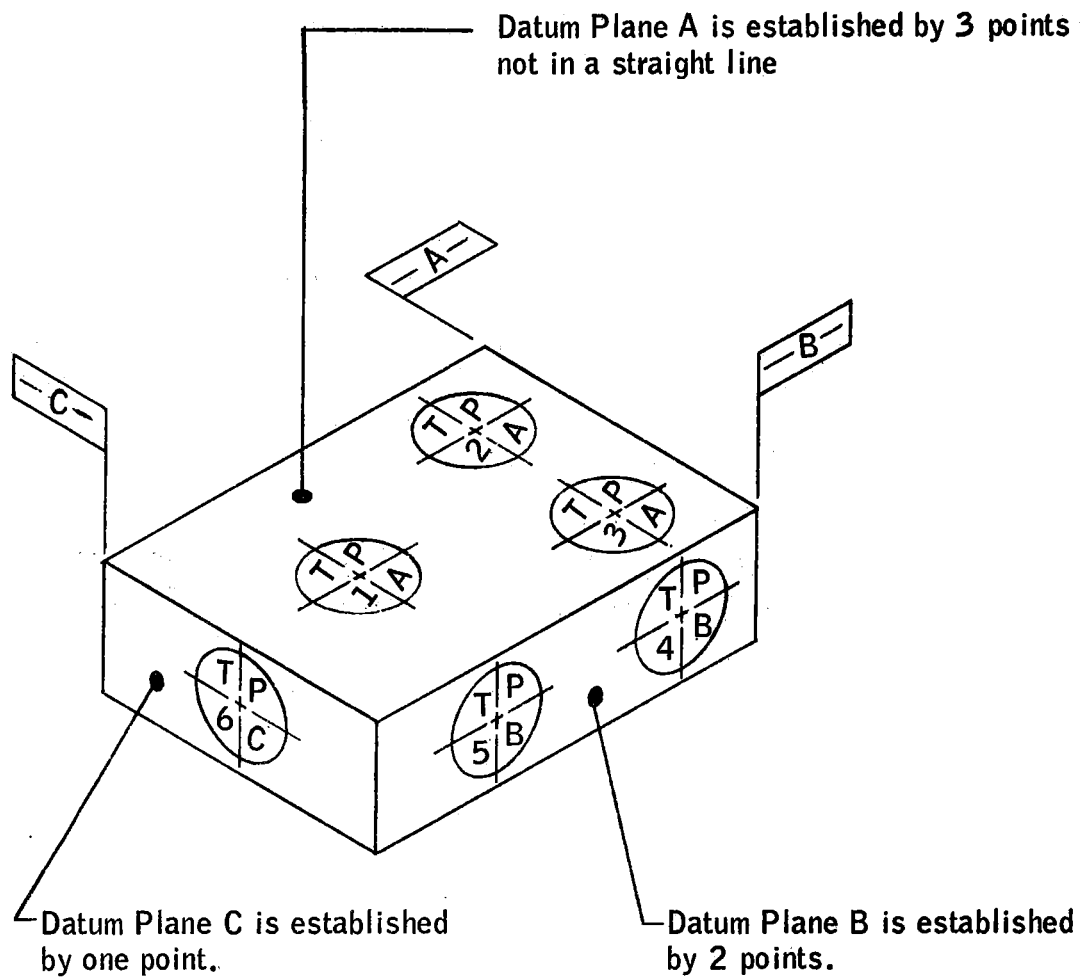
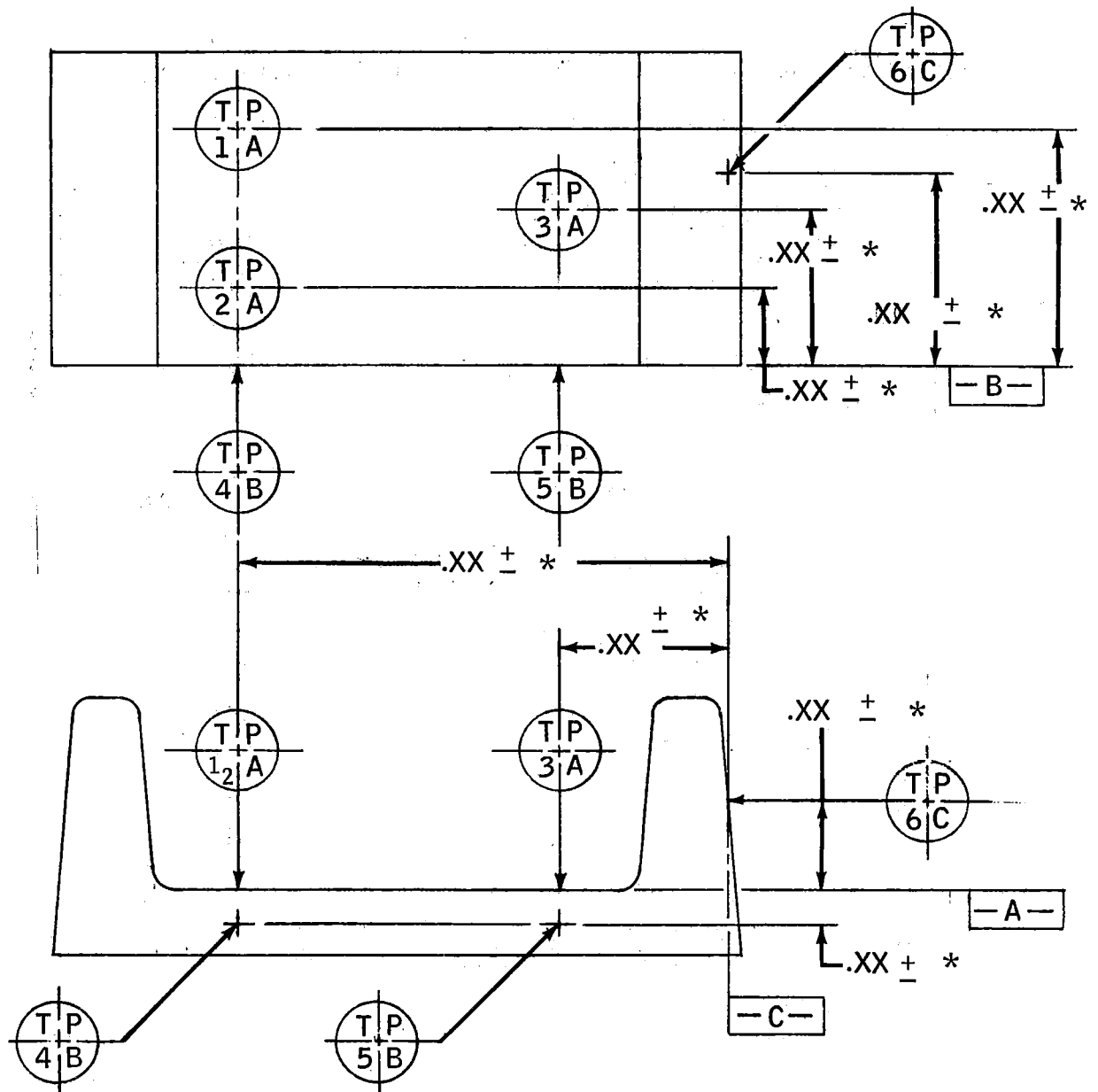


Figure 29-4. Establishment of Datum Planes



* Tolerance as required by design.

Figure 29-5. Use of Tooling Points

CASTINGS

29.6.2 LOCATING PADS

If it is desired that the casting have finished surfaces which can be used for registering surfaces to locate the casting in drill jigs, fixtures, etc., extra pads should be added, if necessary, to meet the requirement. When a surface or pad is machined exclusively for the above purpose, it should be labeled "Nonmandatory - design manufacturer's process" or shown by phantom lines and labeled "For manufacturing purposes only. To be removed before final inspection."

29.7 IDENTIFICATION MARKING

Inspection stamps, serial numbers, vendor identification, heat treat, lot number, etc. should be located in a low stress and unmachined area of the casting, and adjacent to the part number, if possible. The selected area should be a one-inch minimum square, which is capable of being easily supported for stamping.

29.7.1 COMMON IDENTIFICATION FOR RAW CASTING AND MACHINED PART

The part number should be located on a surface which will not be machined during a subsequent manufacturing operation. This shall be indicated by a note on the face of the drawing, or by a symbol referring to a general note, such as: "Cast XXMXXXXX-X on a surface not to be machined with characters .18 minimum high raised $.02 \pm .01$ from the surface."

29.7.2 DIFFERENT IDENTIFICATION FOR RAW CASTING AND MACHINED PART

In order to ensure controlled identification, different identifications may be assigned to the raw casting and the machined part, even though a combined delineation is used. The raw casting will be identified by its pattern, mold or die number, and the machined part by its drawing and part number.

Only the machined part shall be referenced on the next higher level assemblies.

29.7.2.1 Pattern Number

The pattern, mold, or die number consists of the drawing number and the addition of a suffix letter "H" and sequential numbers, thus: "PATT XXMXXXXX-H1" or DIE XXMXXXXX-H1."

The casting shall carry the pattern, mold, or die number on a surface which will not be machined during a subsequent manufacturing operation. This shall be indicated by a note on the face of the drawing, or by a symbol referring to a general note, such as: "Cast XXMXXXXX-HX on a surface not to be machined with characters .18 minimum high raised $.02 \pm .01$ from the surface."

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Ground Support Equipment

CASTINGS

29.7.2.2 Pattern References

In the interest of brevity, the following examples use the word "PATT" to indicate the casting pattern. In actual practice the word "PATT," "MOLD," or "DIE" should be used, depending on the casting process involved.

Casting drawings shall specify the pattern identification near the part number thus: "PATT XXMXXXXX-HX."

When a pattern change is made, the casting drawing referencing the pattern will reflect the change in the pattern number, thus: ~~H1, H2~~, H3, etc.

When a new casting can be produced using an existing pattern, the new drawing will be completely delineated and dimensioned, and will include the material. The drawing will then reference the existing pattern number near the part number, thus: "PATT XXMXXXXX-HX."

The raw casting will then be identified by the existing pattern number referenced on the drawing, and the finished machined part by its drawing and part number.

When a new casting can be produced by altering an existing pattern, the new drawing will be completely delineated and dimensioned, and will include the material. The drawing will then reference the existing pattern by a note near the part number, such as: "PATT XXMXXXXX-HX (make from PATT 00M00000-HX maintaining original)."

If, and when, a pattern change is required that is applicable to both the original pattern and the new casting, then both drawings must be updated to reflect the change.

If, and when, a pattern change is required that is not applicable to both the original pattern and the new casting, then the new casting drawing will be made the master pattern drawing by drawing a line through the reference to the other pattern and adding its own pattern number, thus: ~~PATT 00M00000-HX~~
PATT XXMXXXXX-H1 (make from PATT 00M00000-HX maintaining original)
or (permanent change) or (PATT added) as the case may be.

When a new casting drawing references an existing pattern, both drawings should be cross referenced to each other by adding a note above the title block in 0.18 minimum high letters, such as: "NOTICE: WHEN CHANGING THIS DRAWING SEE (drawing number (s) involved)."



CASTINGS

29.7.2.3 Pattern Number Change

The pattern number will be changed when a revision necessitates a change in the pattern, when the material of the casting is changed, or when a change in a cast-in insert is involved. A pattern is considered to exist once the drawing is issued, and all subsequent pattern changes, including those made while the pattern is under construction, will require a pattern number change as outlined above.

All pattern changes must be recorded in the revision block of the casting detail drawing. The words "PATT CHANGE" must be added in the revision block of the drawing.

29.8 INSPECTION

Castings are normally inspected for three qualities (other than dimensional).

- a. External defects (visual, penetrant and magnetic particle).
- b. Internal defects (radiographic).
- c. Mechanical properties (static destruction test of sample from casting lot).

The casting drawing shall state, either directly or via an inspection specification, the frequency of inspection required, and the acceptance standard for this inspection.

29.8.1 RADIOGRAPHIC INSPECTION

29.8.1.1 General

The use of Radiography as a control procedure, to determine or regulate the soundness of the casting, should be evaluated from the following standpoints:

- a. The effect that the presence of defects would have upon the strength of the casting, or a specific area of a casting.
- b. The presence of undesirable defects in machining areas.

In most cases radiographic inspection of the entire casting is unnecessary. By selecting specific areas, either because of stress or loading conditions, or because of soundness required in machining areas, optimum information can be obtained from the Radiographic process at a minimum of cost.



CASTINGS

29.8.1.1 (Contd)

The Radiographic process will show the presence of shrinkage, sand and dross, porosity, blowholes, cold shuts, mottling, segregation and cracks. Whenever cracks particularly of a surface nature, are of concern, Liquid Penetrant or Magnetic Particle Inspection should be required in addition to radiographic inspection.

29.8.1.2 Specification Reference

In general, radiographic inspection specifications assign casting classifications to indicate the frequency of inspection and quality requirements. The drawing must then reference the applicable inspection specification, and specify the proper classification as determined by the design requirements and the referenced specification. A classification may apply to a complete casting, or several classifications may apply to different areas of one casting.

The specific areas which are selected for radiographic inspection should be detailed showing the extent of the area which should be inspected, and the classification of each area when there are different classifications on a casting. (See Figure 29-7.)

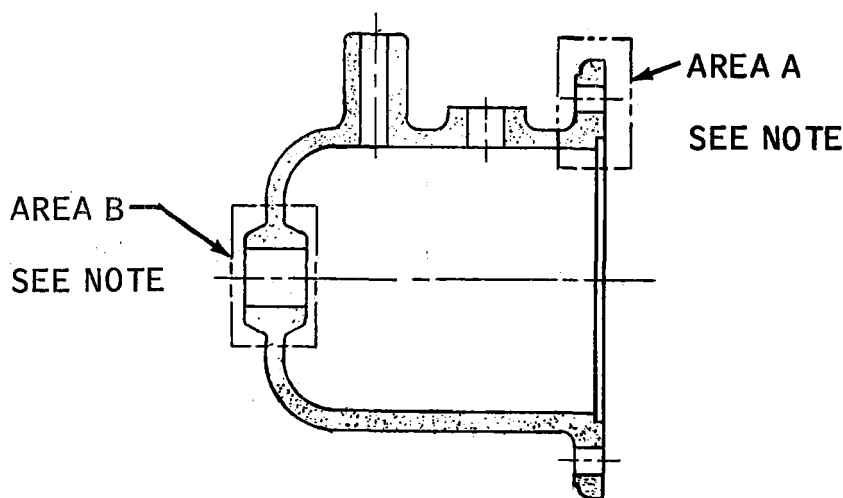


Figure 29-7

29.8.2 INSPECTION SPECIFICATIONS

The following list of specifications is included for the designer's reference and guidance only, and does not imply mandatory usage.

MSFC-STD-100	Castings, Aluminum and Magnesium Alloy, Radiographic Inspection of, Acceptance Standard for
MIL-C-6021	Castings, Classification and Inspection of, for Aeronautical Applications
MIL-R-11469	Inspection, Radiographic, Soundness Requirements for Steel Castings
MIL-STD-453	Inspection, Radiographic
MIL-STD-139	Radiographic Inspection, Soundness Requirements for Aluminum and Magnesium Castings
MIL-I-6868	Inspection Process, Magnetic Particle
MIL-I-6866	Inspection, Penetrant Method of

29.9 NOTES

29.9.1 GENERAL

Where a single drawing for both casting and machining is used, notes shall be listed in two groups, namely, those pertaining to the casting and those pertaining to other miscellaneous operations. The two groups of notes should be separated and headed to denote their use, such as: "Casting Notes" and "Miscellaneous Notes." The Casting notes should be numbered in blocks of ten or twenty inclusive as needed. For example, a combination casting and machining drawing with five casting notes and seven miscellaneous notes would list them as casting notes 1 through 5, miscellaneous notes 11 through 17.

29.9.2 SPECIFIC NOTES

For specific notes, refer to section 9 of this manual.

KEYS AND KEYWAYS

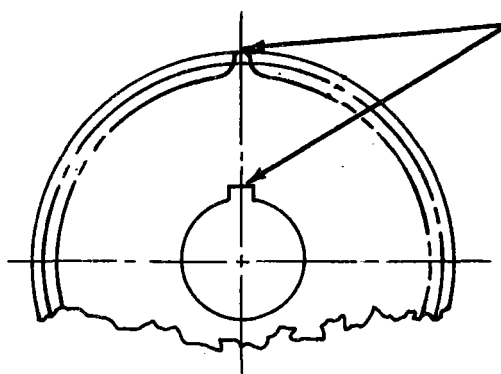
30.1 GENERAL

The keys for general-usage application shall be confined to the straight key and the Woodruff key. The Woodruff key and its keyseat and keyway dimensions are defined in MS35756. Straight key applications shall use a NAS558 whenever practical, and the methods of determining keyway and keyseat dimensions for this key are defined in paragraph 30.4.

30.2 RADIAL LOCATION OF KEYS

Where angular tolerance is not specified, keyways and keyseats can be located at random, even though they may be delineated in line with other keyways, holes, etc.

When a definite location is required, the tolerance should be as liberal as the design permits and specified on the drawing in terms of inches per inch of radius.

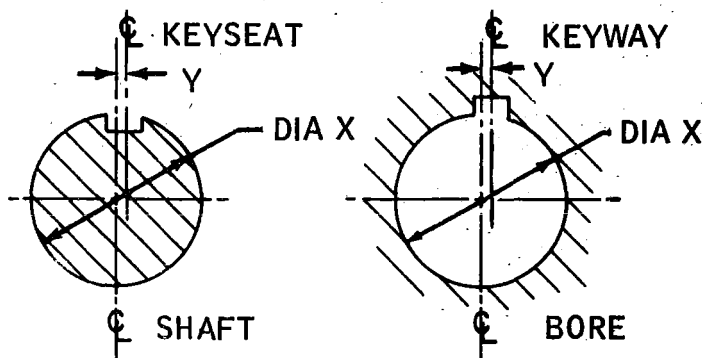


ϕ OF KEYWAY TO BE IN LINE WITH
 ϕ OF TOOTH WITHIN $\pm .XXX$
 MEASURED AT PITCH RADIUS

30.3 KEYWAY LOCATION RELATIVE TO ϕ OF SHAFT OR BORE

To maintain interchangeability (in contrast to individual fit), the ϕ of the keyway and keyseat must align closely with the centerline of the bore or shaft. KSC-STD-168 defines the recommended alignment of these centers as follows:

DIA X		MAX TOL Y
OVER	INCL	
.00	.50	.001
.50	4.00	.002
4.00	-----	.003

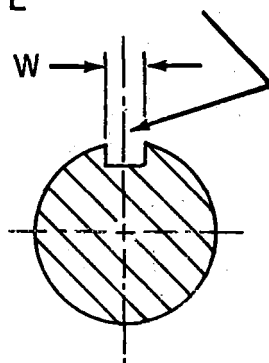


30.3 (Contd)

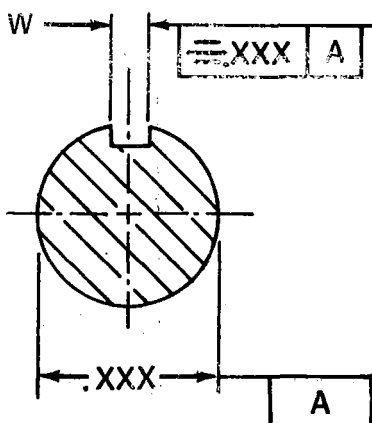
Alignment may be specified on the drawing by one of the following methods:

a. Specific Note

ϕ OF KEYSEAT SHALL ALIGN
 WITH ϕ OF SHAFT WITHIN .XXX



b. Geometric Tolerances





c. Drawing Terms and Tolerances

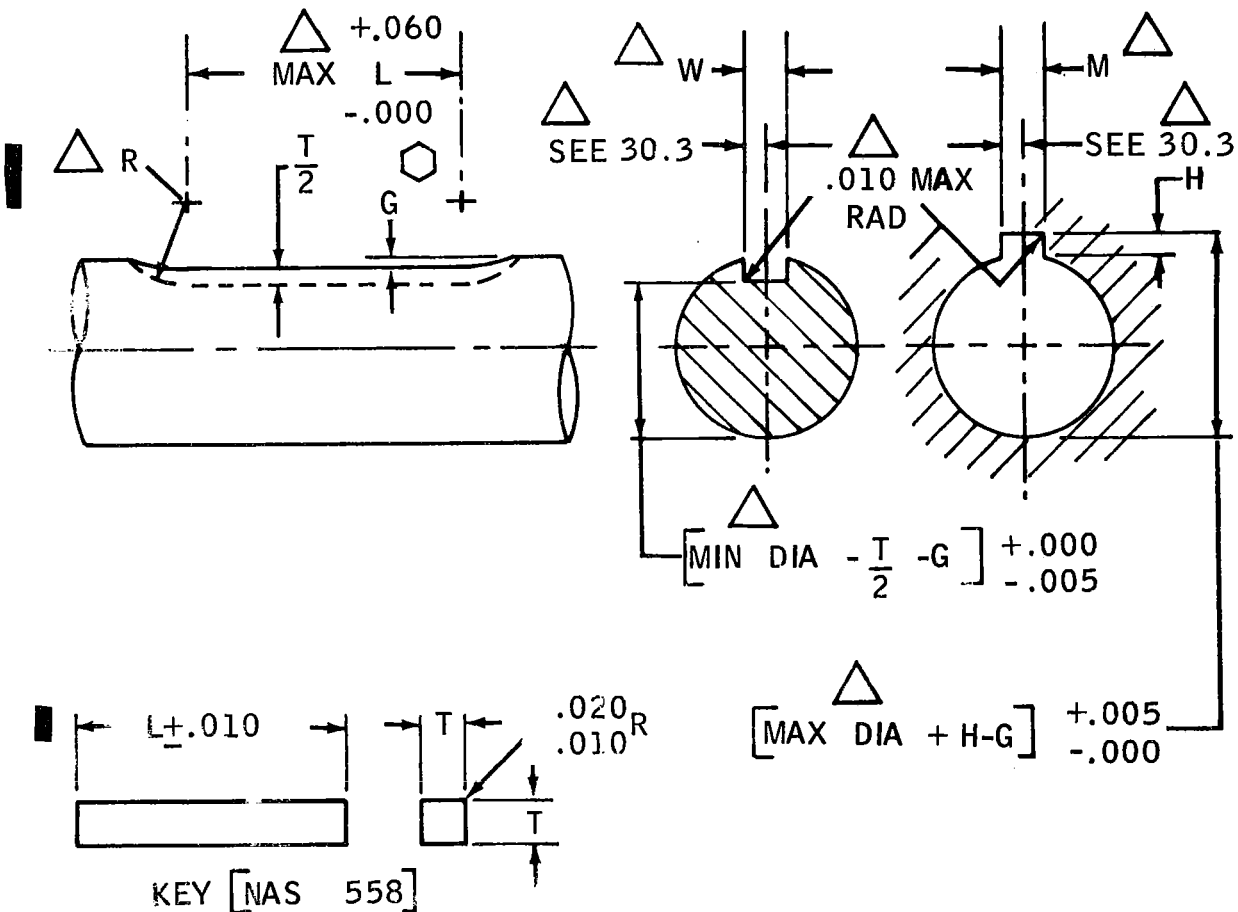
When KSC-STD-168 is referenced as a general note, i.e., "Drawing Terms and Tolerances in accordance with KSC-STD-168, "the alignment of the ϕ shaft and ϕ keyseat need not be specified on the face of the drawing.

KEYS AND KEYWAYS

30.4 DIMENSIONS FOR STRAIGHT KEY

KEY (SQUARE)			KEYSEAT			KEYWAY		
NAS 558	T	Tol	W	Tol	R	M	Tol	H
-404-*	.1250	+.0000 -.0010	.1250	+.0005 -.0010	.194 .190	.1270	±.0010	.0685
-606-*	.1875		.1875	+.0005 -.0012	.384 .380	.1895		.0997
-808-*	.2500		.2500	+.0005 -.0013	.448 .443	.2520		.1310
-1010-*	.3125	±.0010	.3125	+.0005 -.0014	.510 .506	.3145		.1622
-1212-*	.3750		.3750	+.0005 -.0015	.762 .757	.3770		.1935
-1616-*	.5000		.5000	+.0005 -.0015	1.383 1.375	.5020		.2560

* Indicates dash No. expressing length in 16ths.
 Dimensions to appear on detail drawing.
 Values for G may be calculated by the following formula: $G = \frac{D}{2} - \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{W}{2}\right)^2}$
 in which D = Dia of Shaft, W = Width of Keyseat.



SPLINES

31.1 GENERAL

Involute splines are generally used to transmit rotary motion and torsional loads where the design requires variations in the axial lengths during static or dynamic conditions.

Involute splines shall be designed, manufactured, and inspected in accordance with NAS 580 (Internal) and NAS 581 (External) wherever practical.

Unusual application that requires design details not included in NAS 580 and NAS 581 should be designed in accordance with ASA-B5.15, Involute Spline Standards.

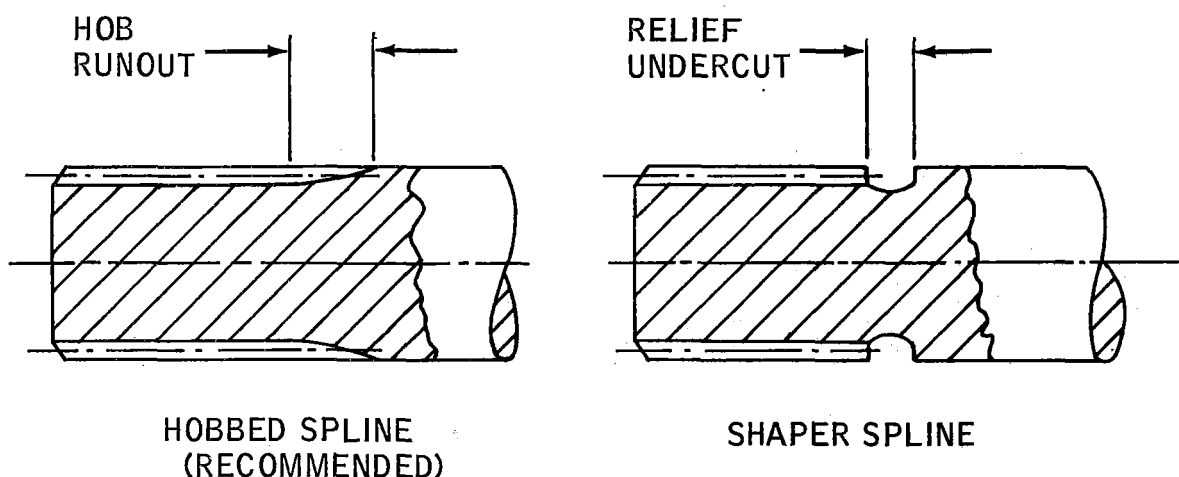
31.2 DESIGN CONSIDERATION

31.2.1 ACTUAL TOOTH CONTACT

Engineering calculations for load-carrying ability should take into consideration that, due to inaccuracies in spacing and tooth form, about 25 percent of the spline teeth contact in actual practice.

31.2.2 EXTERNAL SPLINES (SHAFT)

Where the design permits, the spline to be hobbled (no relief undercut) or shaped (relief undercut), it should be stated on the drawing to facilitate manufacturing.

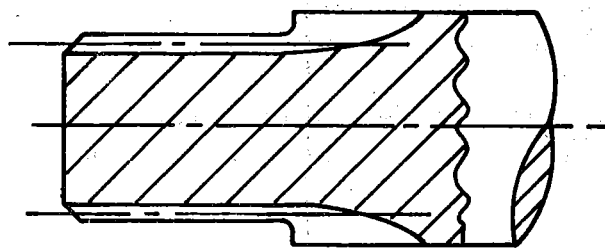




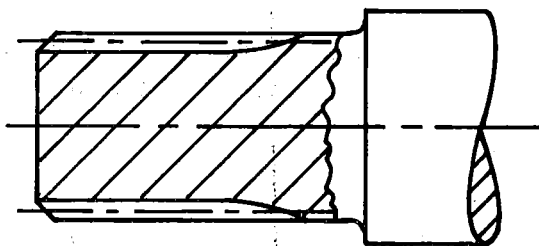
SPLINES

31.2.2.1 Shouldered Shafts

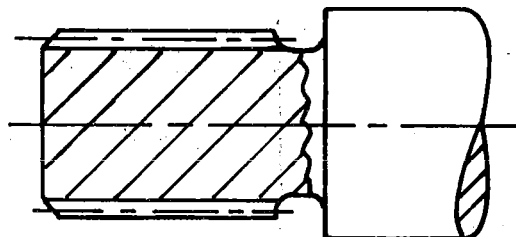
Spline shafts designed with a shoulder may be hobbled through the shoulder.



Or the distance of full spline from the shoulder can be controlled to allow hob to run out before reaching the shoulder.



Or spline may be designed with a relief undercut to be produced on a gear shaper.

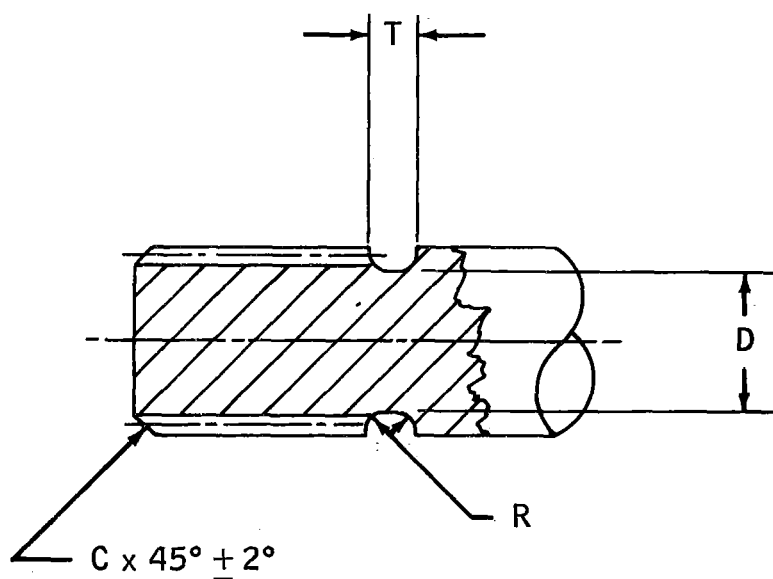


SPLINES

31.2.2.2 Stress Concentration

No serious stress concentration problems arise from the hob runout because of the relatively large radius of the hob. The stress concentration problems of the relief undercuts for shaper-produced splines can be minimized by using as large radii as possible in the relief fillet. Minimum recommended fillets and relief widths are shown in the following table.

EXTERNAL SPLINES					
DIA PITCH	CHAMFER C	MINIMUM RELIEF WIDTH T	RELIEF DIAMETER D		MINIMUM RELIEF FILLET RADIUS R
8/16	$\begin{smallmatrix} +.00 \\ .15 \end{smallmatrix} \begin{smallmatrix} -.02 \\ \end{smallmatrix}$	$\begin{smallmatrix} +.020 \\ .320 \end{smallmatrix} \begin{smallmatrix} -.000 \\ \end{smallmatrix}$.005 less than minor diameter of spline	Tol	$\begin{smallmatrix} +.00 \\ .12 \end{smallmatrix} \begin{smallmatrix} -.03 \\ \end{smallmatrix}$
16/32	$\begin{smallmatrix} +.00 \\ .09 \end{smallmatrix} \begin{smallmatrix} -.02 \\ \end{smallmatrix}$	$\begin{smallmatrix} +.020 \\ .260 \end{smallmatrix} \begin{smallmatrix} -.000 \\ \end{smallmatrix}$		$\begin{smallmatrix} +.000 \\ -.010 \end{smallmatrix}$	$\begin{smallmatrix} +.00 \\ .09 \end{smallmatrix} \begin{smallmatrix} -.03 \\ \end{smallmatrix}$
32/64	$\begin{smallmatrix} +.00 \\ .04 \end{smallmatrix} \begin{smallmatrix} -.01 \\ \end{smallmatrix}$	$\begin{smallmatrix} +.020 \\ .200 \end{smallmatrix} \begin{smallmatrix} -.000 \\ \end{smallmatrix}$			$\begin{smallmatrix} +.00 \\ .06 \end{smallmatrix} \begin{smallmatrix} -.02 \\ \end{smallmatrix}$





SPLINES

31.2.2.2 (Contd)

Hobbed splines should be designed, wherever practical, to accommodate the maximum hob radii shown below.

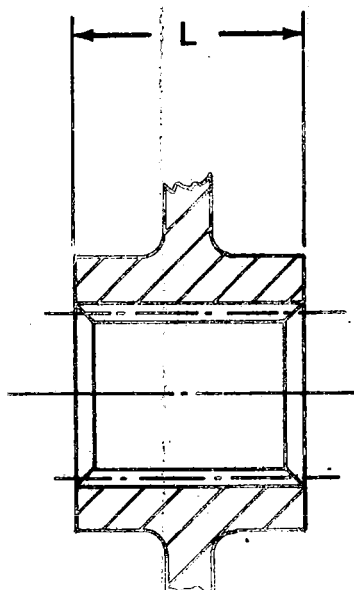
DIA PITCH	MAX HOB RAD	HOB RUNOUT REF
8/16	1.375	.70
16/32	1.250	.50
32/64	1.250	.36

31.2.3 INTERNAL SPLINES

Internal splines are usually produced with a gear shaper or broach. Blind-hole splines are more costly to produce than through-type splines, and should not be specified unless absolutely necessary.

31.2.3.1 Through Splines

Through splines may be produced with a gear shaper or broach. To provide for sufficient chip space in broaching, the length "L" should not be more than 1.5 times the pitch diameter.

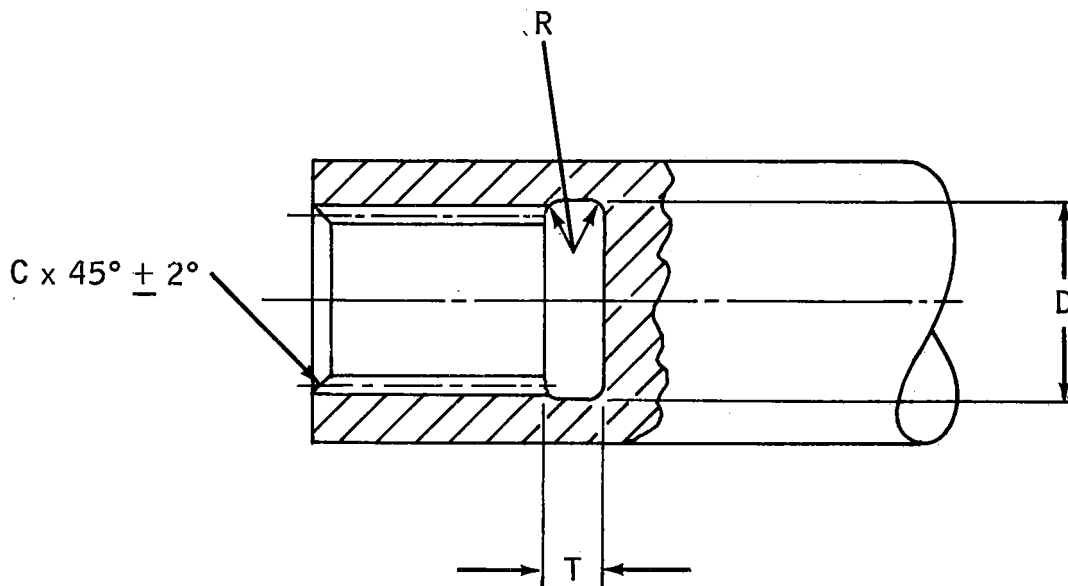


SPLINES

31.2.3.2 Blind-Type Splines

Blind-Type splines may be produced with a gear shaper only, and require cutter and chip clearance relief as shown in the following table. Relief widths shown are minimum; where possible, wider reliefs should be used and more liberal tolerances applied.

DIA PITCH	INTERNAL SPLINES				
	CHAMFER C	MINIMUM RELIEF WIDTH T	RELIEF DIAMETER D		MINIMUM RELIEF FILLET RADIUS R
8/16	$.15 \begin{smallmatrix} +.00 \\ -.02 \end{smallmatrix}$	$.360 \begin{smallmatrix} +.030 \\ -.000 \end{smallmatrix}$.005 more than max major dia of spline	Tol $\begin{smallmatrix} +.010 \\ -.000 \end{smallmatrix}$	$.12 \begin{smallmatrix} +.00 \\ -.03 \end{smallmatrix}$
16/32	$.09 \begin{smallmatrix} +.00 \\ -.02 \end{smallmatrix}$	$.300 \begin{smallmatrix} +.030 \\ -.000 \end{smallmatrix}$			$.09 \begin{smallmatrix} +.00 \\ -.03 \end{smallmatrix}$
32/64	$.04 \begin{smallmatrix} +.00 \\ -.01 \end{smallmatrix}$	$.240 \begin{smallmatrix} +.030 \\ -.000 \end{smallmatrix}$			$.06 \begin{smallmatrix} +.00 \\ -.02 \end{smallmatrix}$



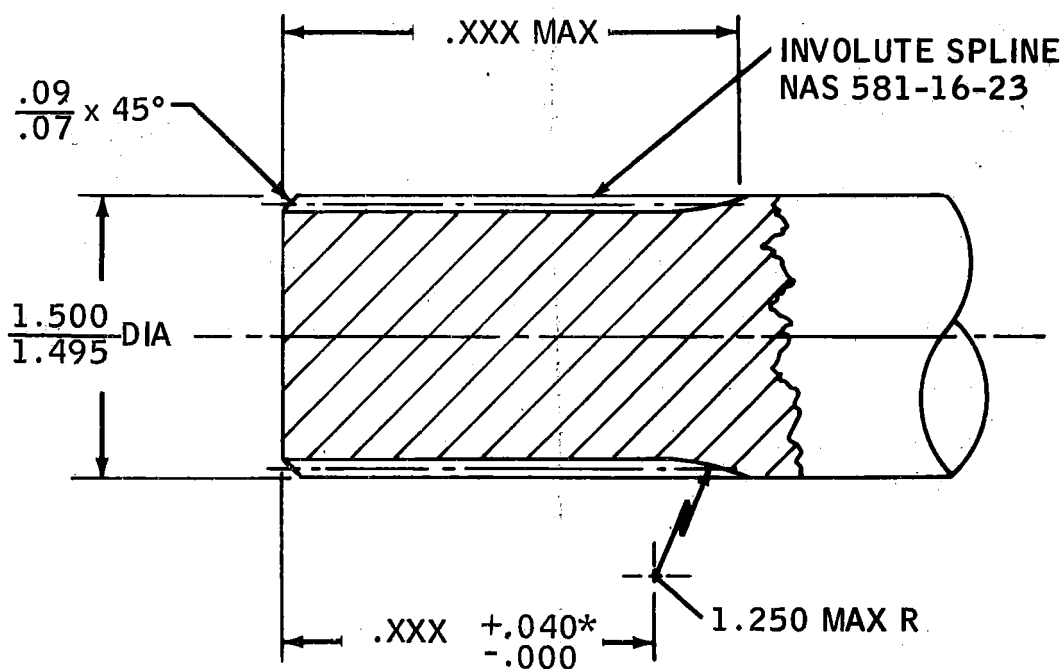


SPLINES

31.3 DETAIL REQUIREMENTS

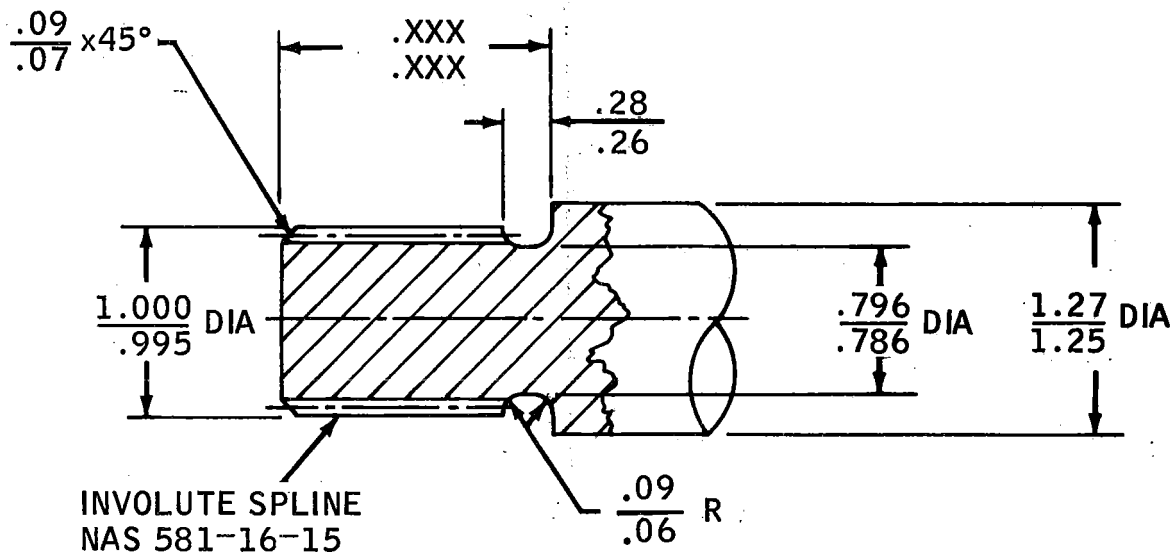
The following illustrations are typical examples of spline callouts and detail dimensions required:

31.3.1 HOBBED SPLINE (EXTERNAL)



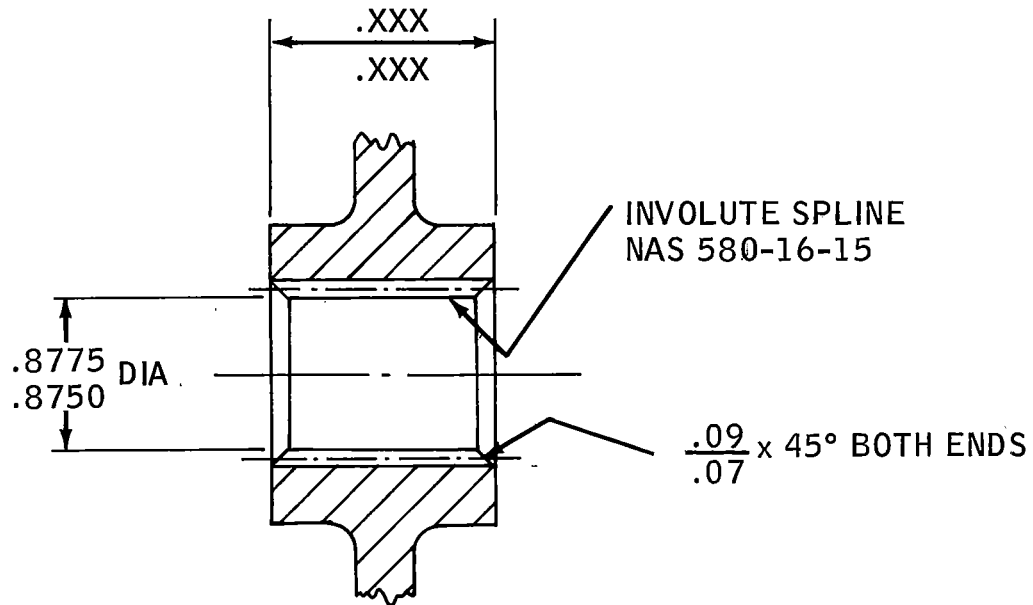
*Minimum recommended tolerance; use larger tolerance where design permits.

31.3.2 SHAPER SPLINE (EXTERNAL)

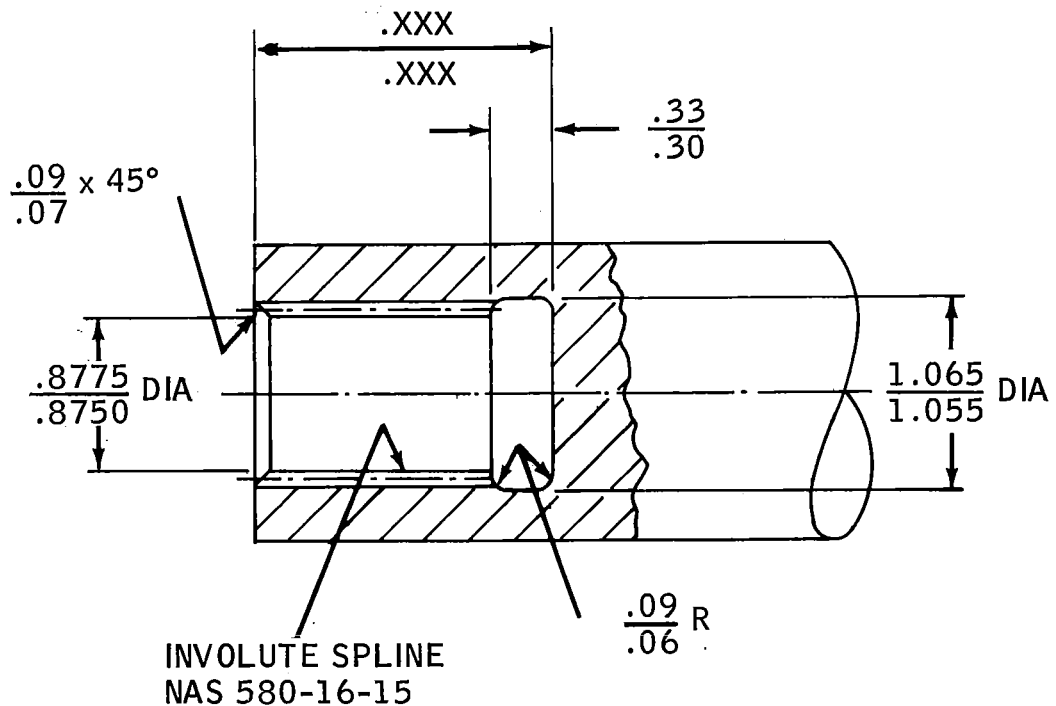


SPLINES

31.3.3 THROUGH SPLINE (INTERNAL)



31.3.4 BLIND SPLINE (INTERNAL)



GEARS

32.1 INTRODUCTION

The design and manufacture of gears are specialized endeavors which range from a crude art to an engineering science. Because of the many interdependent factors involved in applying gearing, attempting to completely cover the design of gearing in this section is not feasible. Numerous texts, both commercial and noncommercial, on the subject, are available.

32.2 TYPES OF GEARS

The first logical step in the design of a gear train is to pick the kind of gear for the application. Paragraphs 32.2.1 through 32.2.6 give brief descriptions of each type of gearing.

The size of gears to be used, the kind of steel or other material, and the tooth accuracy will depend considerably on the speed and load conditions under which the train is to be operated. Many designs hinge on the nature of the apparatus to which the gearing will be attached. In many cases, gear trains will be integral parts of larger machines, and the center distances and permissible face widths will be considerably limited by available space within the machine structure. Under such conditions, the designer will usually start with the size and shape gearing that will fit the machine, then he will make the necessary calculations of load-carrying capacity to determine if it is possible to provide suitable gearing that can be manufactured at a reasonable cost. In some cases, the gearing is used primarily to transmit motion rather than power, and gear sizes will be established more by accuracy requirements than by power requirements.

32.2.1 SPUR GEARS

Spur gears, the most common form of gearing, are used to transmit power or motion between parallel shafts or between a shaft and a rack. They are usually hobbled, shaped, milled, stamped, drawn, or cast and may be further finished by grinding, shaving, lapping, or burnishing. The processes used depend on several factors: cost, quantity of production, size, speed, load to be transmitted, degree of accuracy of angular motion desired, and permissible noise.

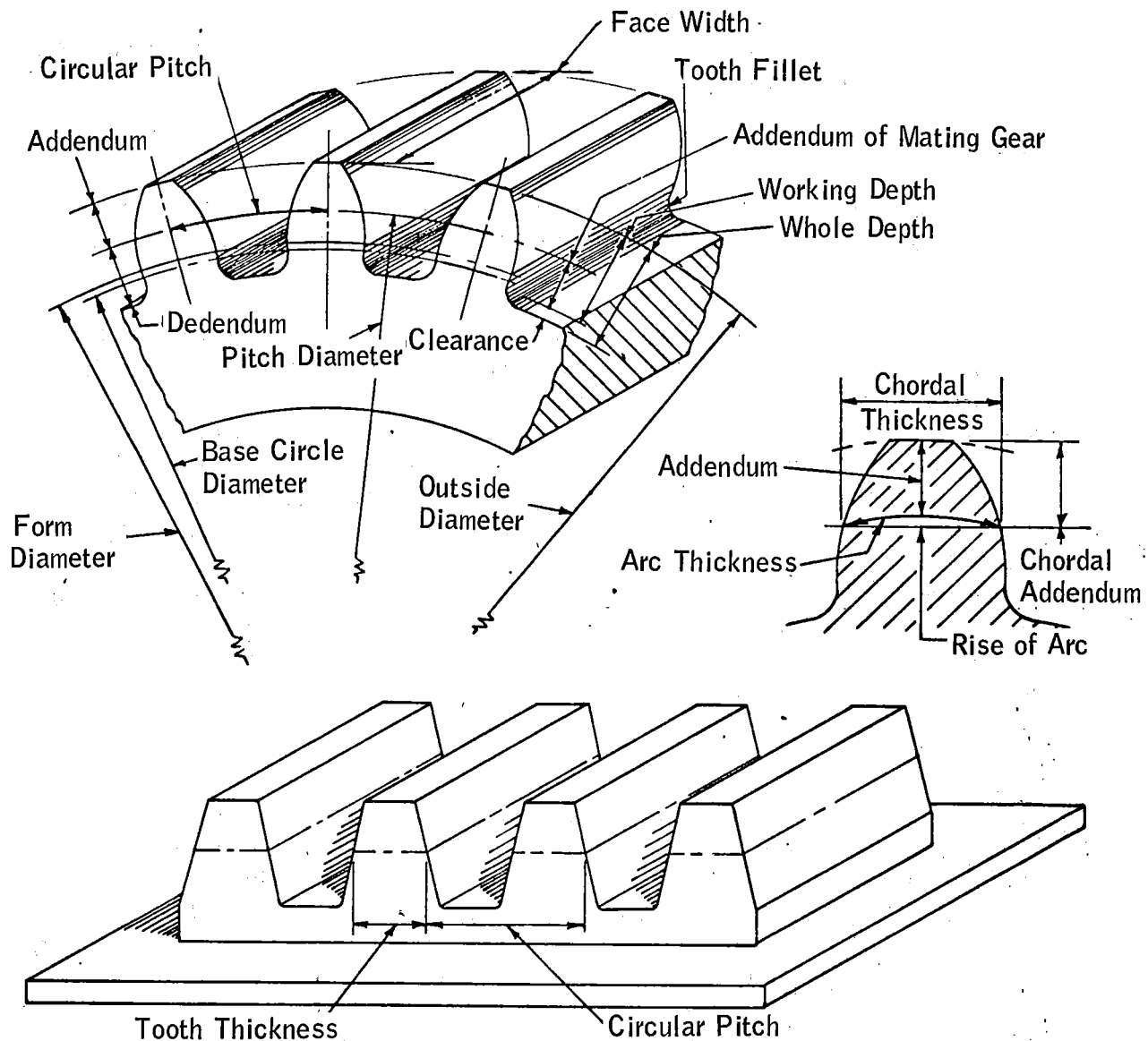
Spur gears are most commonly made to, but not necessarily restricted to, the following diametral pitches: 2, 2-1/4, 2-1/2, 3, 4, 5, 6, 8, 10, 12, 16, 20, 24, 32, 40, 48, 64, 80, 96, and 120. The standard pressure angle is 20 degrees.



GEARS

32.2.1 (Contd)

Common Terminology associated with a typical spur gear and spur rack is illustrated below:



32.2.2 HELICAL GEARS

Helical gears are usually preferred to spur gears when transmission of power at high speeds, smooth operation, or quietness is desired. They are not as commonly used as spur gears, because all cutting equipment is not capable of producing helical teeth. With some types of equipment, helicals can be produced with special tool modifications. Helical gears may

GEARS

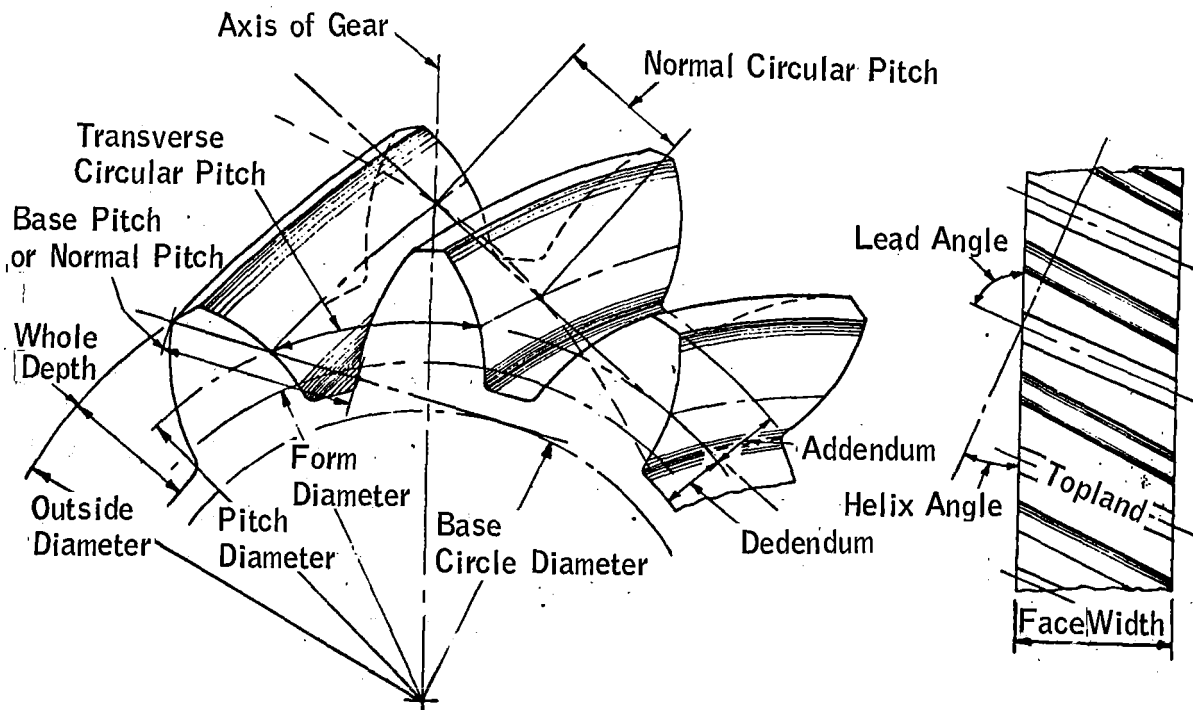
32.2.2 (Contd)

be right or left hand (a right-hand gear meshing with a left-hand pinion or vice versa). Because of the axial thrust produced by the helix angle of the teeth, special attention must be given to the design of the bearings to support thrust loads.

In general-purpose applications, the same normal diametral pitch is frequently used for helical gears as would be used for the diametral pitch of spur gears so that the same hobs may be used for both types. The commonly used diametral pitches are 2, 2-1/4, 2-1/2, 3, 4, 5, 6, 8, 10, 12, 16, 20, 24, 32, 40, 48, 64, 80, 96, and 120. As in the case of spur gears, the preferred pressure angle for helical gears is 20 degrees. If a 20-degree pressure angle spur gear hob is used to cut a helical gear, the normal pressure angle of the helical will be 20 degrees, but the transverse pressure angle will be somewhat larger.

Where maximum load-carrying capacity is required, special tooth proportions are used, and it is necessary to design special hobs which are not the same as used to cut standard spur gears.

The application of the more commonly used terms associated with a typical involute helical gear is illustrated below:





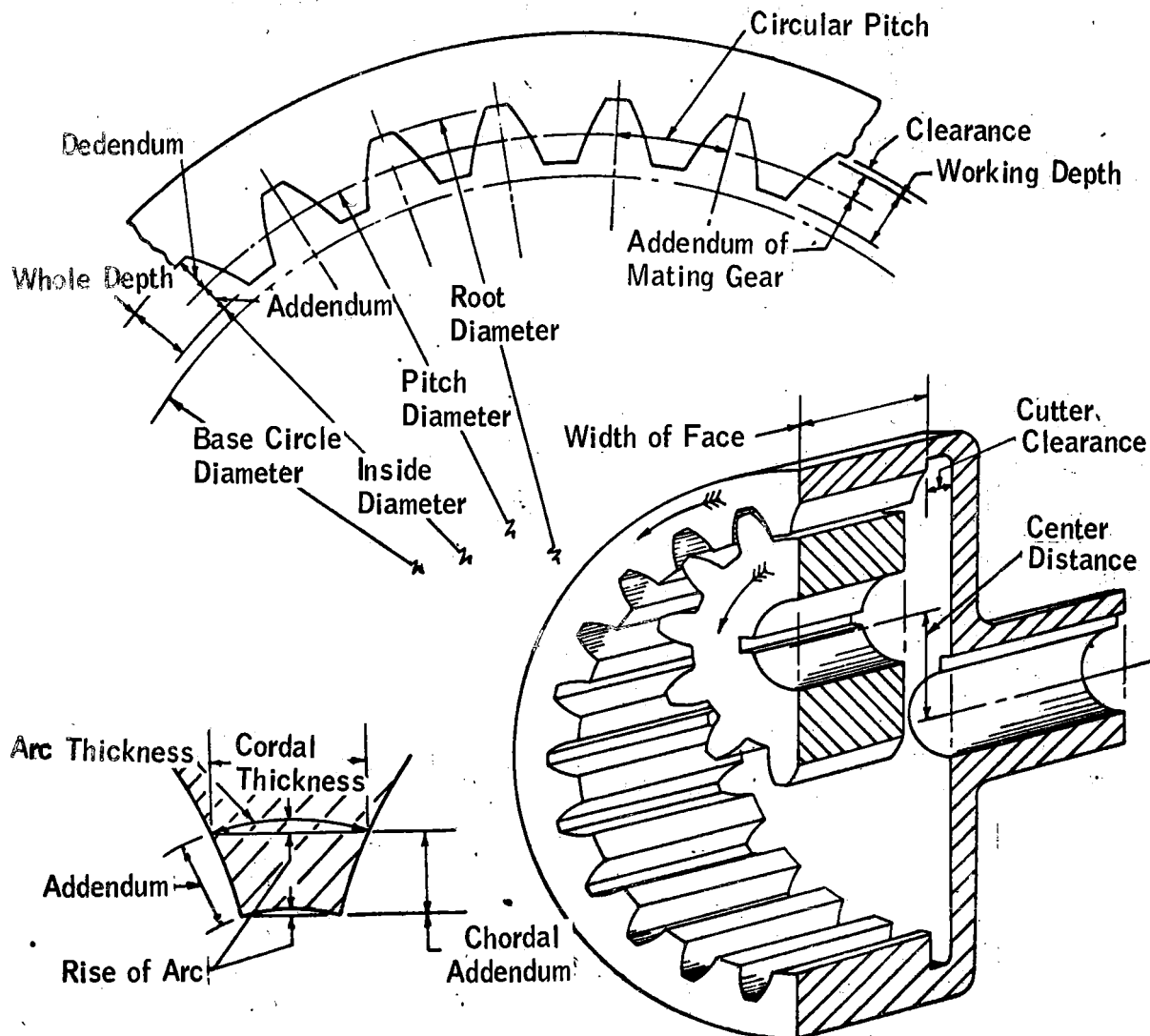
GEARS

32.2.3 INTERNAL GEARS

Internal gears are used in planetary gear drives, when design limitations make a short center distance desirable or when a guard over the gear teeth is necessary. The teeth may be either spur or helical. In the latter case, both pinion and gear must be the same hand. Internal gears can be cast, stamped, shaped, or milled and may be further finished by grinding, shaving, lapping, or burnishing. More complicated tooling may be required for internal gears than for spur gears of the same size, and the same degree of accuracy is not always possible, especially in gears of small pitch diameter.

The preferred pressure angle for general application is 20 degrees. The commonly used diametral pitches are 2, 2-1/4, 2-1/2, 3, 4, 5, 6, 8, 10, 12, 16, 20, 24, 32, 40, 48, 64, 80, 96, and 120.

Common terminology associated with a typical internal gear and pinion is illustrated below:



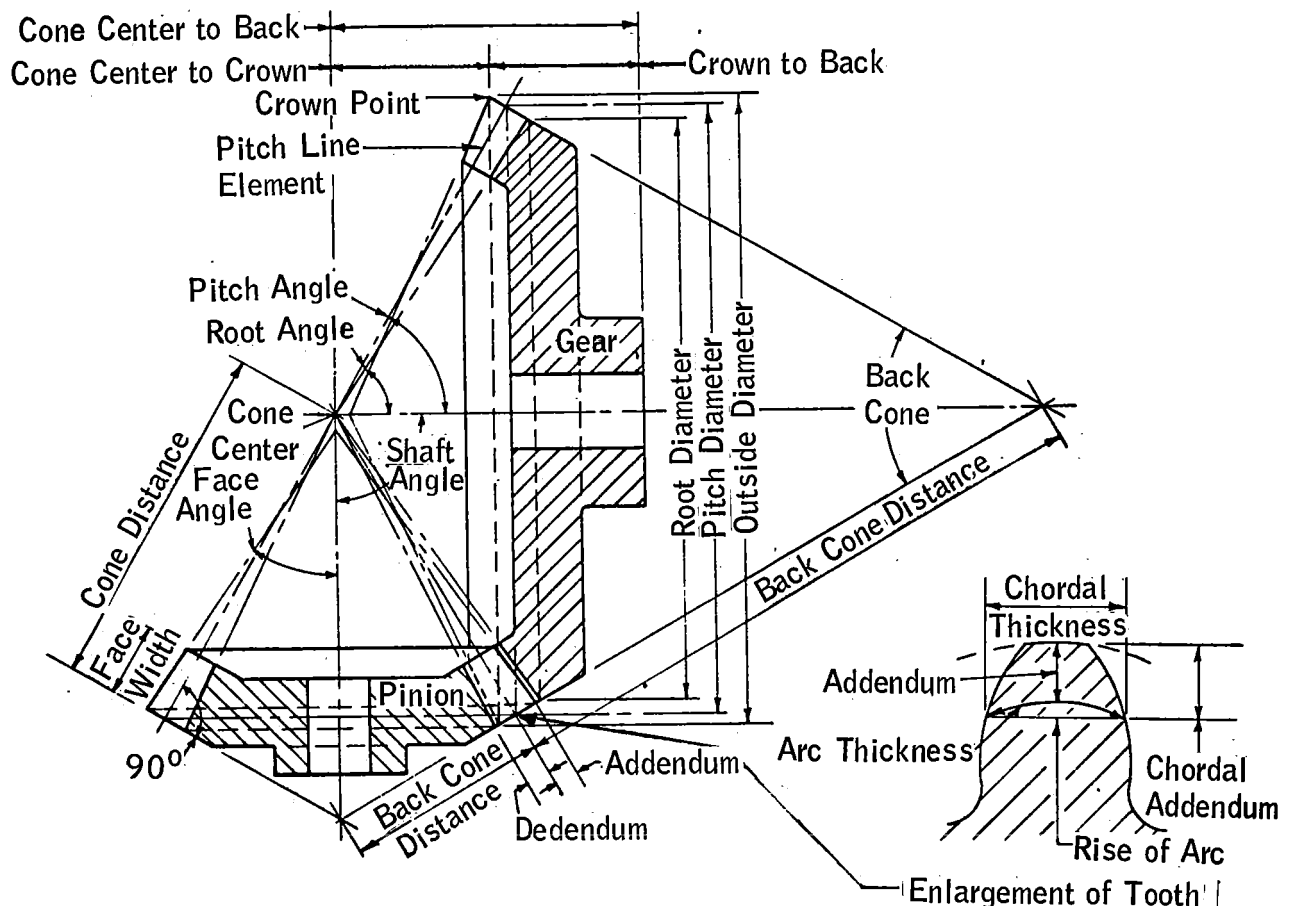
GEARS

32.2.4 BEVEL GEARS

Bevel gears are the most commonly used means of transmitting power or motion between nonparallel shafts. They are usually manufactured by the generating process using milling, shaping, or grinding, but they can be cast. Finishing may be by grinding, lapping, or burnishing.

Of the various types of bevel gears, the straight bevel gears have the simplest design and are often used when speeds and loads are comparatively low. They have lower axial thrust than the usual types of spiral or hypoid gears.

Spiral bevel gears are to be preferred to straight bevels when high load-carrying capacity or low noise level are of major importance. In most cases, they are cheaper to manufacture than straight bevels, if made in quantity, but the mounting design must provide for the additional thrust which is characteristic of this type of bevel gear.



GEARS

32.2.4 (Contd)

Zero bevel gears are spiral bevel gears with zero spiral angles. They lie in an intermediate position between straight and spiral bevels in respect to thrust load carrying capacity and quietness.

Hypoid gears are designed for nonintersecting axes and possess greater load-carrying capacity and quietness than spiral bevel gears of equivalent ratio. They can be made for high ratios, similar to worm gear combinations, and have greater operating efficiency than worm gears of equivalent reduction. As a class, they fall between spiral bevels and worm gears and retain many of the advantages of each.

32.2.5 FACE GEARS

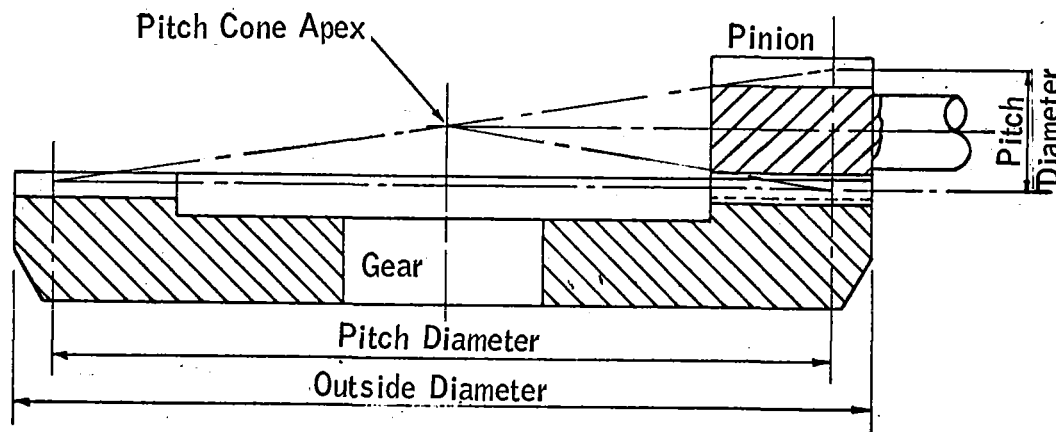
A face gear is a form capable of meshing with a spur pinion on axes that are nonparallel (normally at 90 degrees) and may be either intersecting or nonintersecting. Their use is limited to relatively low speeds and low loads or to applications where accuracy of tooth spacing is not important. The principal advantage of face gears lies in the fact that considerable axial displacement of the pinion is possible without affecting their operation.

Face gears can be shaped or cast and may be finished by lapping or burnishing. Mating pinions may be made by any of the conventional methods of spur gear manufacture.

The face width of the tooth of a face gear is limited at the outside end by the radius where the tooth becomes pointed or slightly beyond and at the inside end where the pressure angle is zero. Practical considerations usually place the face width short of these limits.

The preferred pressure angle is 20 degrees, and any of the spur gear diametral pitches can be used.

Common terminology associated with a typical face gear and pinion is illustrated below:



GEARS

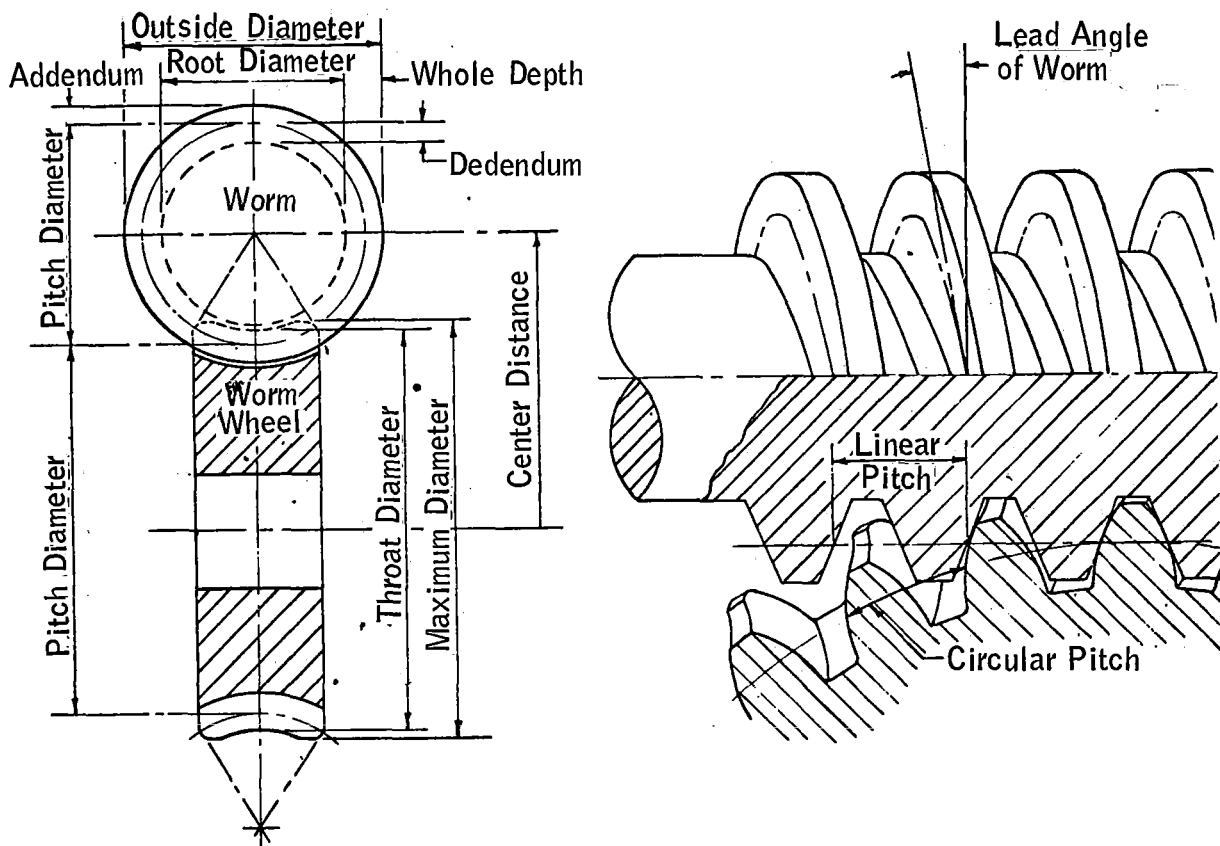
32.2.6 WORM GEARS

Worm gearing is used to transmit power or motion between nonparallel, nonintersecting shafts. A high ratio is easily obtained with this type of gearing. If the lead angle of the worm is less than 6 degrees, the worm gear set will frequently be self-locking when power is applied to the gear. To obtain efficiency of 85 percent or better, it is usually necessary to use a worm lead angle of at least 15 degrees. In general, worm gearing is not as efficient as bevel gearing, but it offers a lower cost and more compact means of handling high reduction ratios.

Worms are milled, hobbled, ground, or cut on a lathe. Worm wheels are usually hobbled.

The size of worm threads is generally specified by linear pitch instead of diametral pitch. Preferred linear pitches are .030, .040, .050, .065, .080, .100, .130, .160, .200, .250, .300, 0.400, .500, .625, .750, 1.000, 1.250, and 1.500. If diametral pitches are used, they should be picked the same as for spur gears.

Common terminology associated with worm gearing is illustrated below:



GEARS

32.3 GEAR DETAILS

Gears may be procured as a catalog item from several sources when the design permits. In this case, the ordering data shall be as required by the manufacturer and to suit the design and inspection requirements.

When it becomes necessary to design the gearing for a unit and provide detail drawings of gears for manufacture, inspection, and interchangeable operation, the amount of data that should appear on the drawing will depend on the purpose for which the gear is used. The following paragraphs describe the different gear specifications that may appear on a drawing. Drawings should be as complete as possible to avoid confusion and misinterpretation of engineering requirements.

32.3.1 GEAR TOOTH SPECIFICATION DATA

In Table 32-1, items marked "D" are usually shown on the gear detail drawing in views, tabulations, notes, or charts. In some cases, a separate gear blank drawing may contain some of this data.

I NUMBER OF TEETH

Number of teeth is required data. It is desirable to secure a "hunting tooth" ratio in which there is no common factor between the gears and pinion teeth. This balances wear and makes the gears last longer and run more quietly.

II DIAMETRAL PITCH

Diametral pitch is required data.

Recommended diametral pitches are:

	FOR SPUR HELICAL GEARS	FOR BEVEL GEARS
MEDIUM PITCH	2, 2-1/4, 2-1/2, 3, 4, 6, 8, 10, 12, and 16	6, 8, 10, 12, and 16
FINE PITCH	20, 24, 32, 40, 48, 64, 80, 96 and 120	20, 24, 32, 40, 48 and 64



GEARS

TABLE 32-1

ITEM	SUBJECT	SPUR			HELICAL			BEVEL		
		REQUIRED	OPTIONAL	CERTAIN APPLI- CATION	REQUIRED	OPTIONAL	CERTAIN APPLI- CATION	REQUIRED	OPTIONAL	CERTAIN APPLI- CATION
I	NUMBER OF TEETH	D			D			D		
II	DIAMETRAL PITCH	D			D			D		
III	PITCH DIAMETER	D			D			D		
IV	PRESSURE ANGLE	D			D			D		
V	WHOLE DEPTH	D (1)			D (1)			D		
VI	TOOTH THICKNESS, ARC	D (2)			D (2)					
VII	TOOTH THICKNESS, CHORDAL	D (2)			D (2)					
VIII	NORMAL PRESSURE ANGLE				D					
IX	NORMAL CIRCULAR PITCH				D					
X	HELIX ANGLE				D					
XI	TYPE & FORM OF TOOTH			D			D	D		
XII	SHAFT ANGLE							D		
XIII	ROOT ANGLE							D		
XIV	SPIRAL ANGLE							D (3)		
XV	HAND OF SPIRAL							D (3)		
XVI	OUTSIDE DIAMETER	D			D			D		
XVII	FACE WIDTH	D			D			D		
XVIII	ROOT DIAMETER	D (1)			D (1)					
XIX	MATERIAL & HEAT TREATMENT	D			D			D		
XX	HAND OF HELIX				D					
XXI	PITCH ANGLE							D		
XXII	CONE DISTANCE							D		
XXIII	FACE ANGLE							D		
XXIV	PITCH CONE APEX TO CROWN							D (4)		
XXV	CROWN TO BACK							D (4)		
XXVI	PITCH CONE APEX TO BACK							D (4)		
XXVII	THICKNESS OF BLANK							D		
XXVIII	REFERENCE AXIS & MTG SURFACE			D			D	D		
XXIX	HYPOID OFFSET							D (5)		
XXX	CROWN TO CROSSING POINT								D (5)	
XXXI	ADDENDUM		D			D			D	
XXXII	CIRCULAR PITCH		D			D			D	
XXXIII	CHORDAL ADDENDUM			D			D		D (6)	
XXXIV	TIP RADIUS			D			D		D	
XXXV	END RADIUS			D			D		D	
XXXVI	ROOT FILLET RADIUS			D			D			
XXXVII	FORM DIAMETER			D			D			
XXXVIII	PROFILE CHART			D			D			
XXXIX	DIA OVER PINS			D			D			
XL	MOUNTING DISTANCE								D	
XLI	CIRCULAR TOOTH THICKNESS								D (6)	
XLII	CHORDAL TOOTH THICKNESS								D (6)	
XLIII	TOOTH ANGLE									D (7)
XLIV	LIMIT POINT WIDTH									D (7)
XLV	TOOL ADVANCE									D (7)
XLVI	FACE CONTACT RATIO								D	
XLVII	CORNER ROUND									D

(1) Either whole depth or root diameter may be specified.

(2) Either arc or chordal may be specified.

(3) These items are required on spiral bevel and hypoid gears only.

(4) Drawing may show both "Pitch Cone Apex to Crown" and "Crown to Back" or "Pitch Cone Apex to Back".

(5) These items are required on hypoid gears only.

(6) Drawings usually show "Circular Tooth Thickness" only or "Chordal Tooth Thickness" and "Chordal Addendum".

(7) These items may be required for straight bevel gears only.



GEARS

32.3.1 (Contd)

III PITCH DIAMETER

Pitch diameter is required data.

$$\text{The nominal pitch diameter} = \frac{\text{Number of teeth}}{\text{Diametral pitch}}$$

The pitch diameter of a bevel gear is at the intersection of the pitch cone and the back cone.

IV PRESSURE ANGLE

Pressure angle is required data.

Spur gears-----Use 20 degrees.

Helical gears -----It is desirable to use the same pressure angle (20 degrees) as for spur gears. This will give a special normal pressure angle for each helix angle.

Bevel gears-----The standard pressure angle for all types of bevel gears should be 20 degrees. In zerol gearing, pressure angles of 22-1/2 degrees or 25 degrees may be used to avoid undercut in some cases.

V WHOLE DEPTH

Whole depth is a required item for bevel gears. For spur and helical gears, either whole depth or root diameter may be specified.

VI TOOTH THICKNESS (ARC) OR VII TOOTH THICKNESS (CHORDAL)

Either of these items is required data on spur and helical gears only. It is customary to achieve the required backlash by reducing the thickness of the gear teeth by a suitable amount. In many cases, the tooth thickness is measured indirectly by diameter over pins or with a master gear. The tooth thickness value should be specified as a reference dimension when other dimensions are used to control tooth thickness. It is necessary to have this dimension in order to make calculations and check data.



Ground Support Equipment

GEARS

32.3.1 (Contd)

VIII NORMAL PRESSURE ANGLE

Normal pressure angle is required data on helical gears only.

$$\tan \phi_n = \tan \phi \cos \omega$$

ϕ_n = Normal Pressure Angle

ϕ = Pressure Angle

ω = Helix Angle

IX NORMAL CIRCULAR PITCH

Normal circular pitch is required data on helical gears only.

$$\text{Normal circular pitch} = \text{Circular Pitch} (\cos \omega)$$

X HELIX ANGLE

Helix angle is required data on helical gears only. Recommended helix angles are 15 degrees and 23 degrees for single helix gears and 30, 35, and 45 degrees for double helix gears. Thrust loads will limit the maximum helix angle for single helix gears. The helix angle must be large enough to provide a sufficient number of axial crossovers.

XI TYPE AND FORM OF TOOTH

Type and form of tooth are required data on bevel gears. The type of tooth (straight, zero, or spiral) and the form of the tooth (coniflex, formate, or spheroidal) should be specified.

On spur and helical gears, certain applications will require specification of the tooth form. For general purpose, the tooth form shall be considered a full-depth, 20-degree pressure angle involute tooth form.

XII SHAFT ANGLE

Shaft angle is required on bevel gears only. The shaft angle is the included angle between the axes of the shafts. This angle is equal to the sum of the pitch angles of the gear and pinion. The shaft angle is generally fixed by the requirements of the mounting.

GEARS

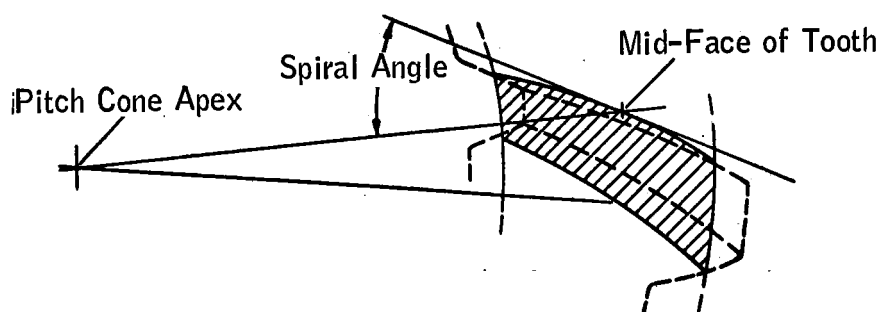
32.3.1 (Contd)

XIII ROOT ANGLE

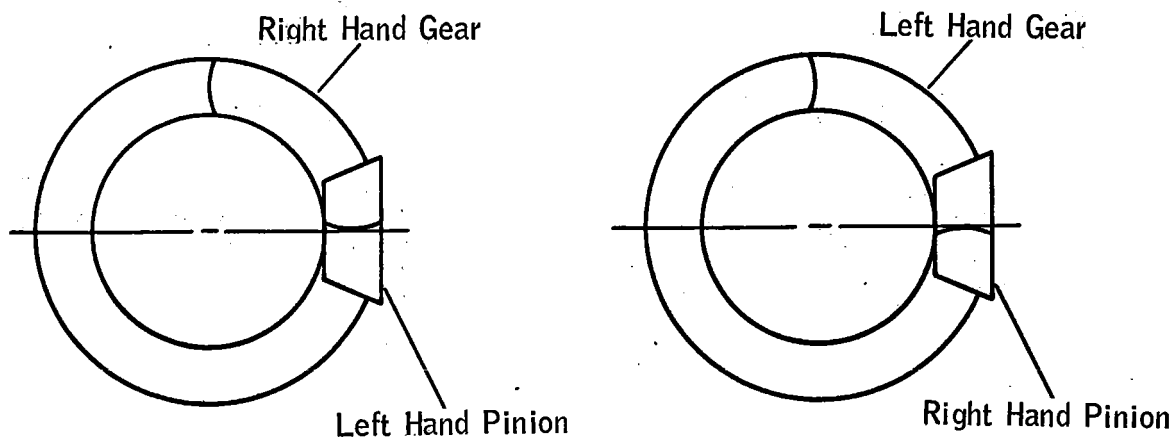
Root angle is required data on bevel gears only.

XIV SPIRAL ANGLE

Spiral angle is required on spiral bevel gears and hypoid gears. The spiral angle is the angle between an element of the pitch cone and a line normal to the tooth profile, passing through a point at midpoint on the face of the tooth.

**XV HAND SPIRAL**

Hand of spiral is required on spiral bevel and hypoid gears only. The hand of spiral is denoted by the direction in which the teeth curve, i.e., left-hand teeth incline away from the axis in the counterclockwise direction when viewed toward the face of the gear, and right-hand teeth incline away from the axis in a clockwise direction.





Ground Support Equipment

GEARS

32.3.1 (Contd)

XVI OUTSIDE DIAMETER

Outside diameter is required data. The outside diameter on a bevel gear is the intersection of the face cone and back cone.

XVII FACE WIDTH

Face width is required data. In general, the face width for spur and helical gears shall not exceed the pitch diameter of the pinion. The pinion face width is usually made wider than the gear so that the total face width of the gear will always be in contact with the pinion.

The face width of bevel gears is limited. The small ends of the teeth should not be extended toward the pitch cone apex beyond a point that prohibits the teeth from carrying the load. Deflection of mounting, bearing, or shafting often allows the contact area to shift toward the small end of the teeth. The designer must make sure that the small ends of the teeth are of adequate size to carry this type of loading.

XVIII ROOT DIAMETER

Root diameter is required data on spur and helical gears only. Either root diameter or whole depth may be specified. Unless teeth are highly loaded, the root diameter is not generally specified.

XIX MATERIAL AND HEAT TREATMENT

Material is required data. The heat treatment and hardness of the gear should be specified on the drawing when the gear material is heat treated in some stage of the gear manufacture.

XX HAND OF HELIX

Hand of helix is required data on helical gears only.

XXI PITCH ANGLE

Pitch angle is required data on bevel gears only.

XXII CONE DISTANCE

Cone distance is required data on bevel gears only. The cone distance is the linear distance from the pitch cone apex to the back cone measured along the pitch cone.

32.3.1 (Contd)

XXIII FACE ANGLE

Face angle is required data on bevel gears only. The face cone angle and position of the face cone apex are designed so that the clearance between the top lands and the root lands of the mating teeth is uniform from the large to the small ends of the teeth. This is known as parallel clearance.

XXIV PITCH CONE APEX TO CROWN

Pitch cone apex to crown is required data on bevel gears only. Pitch cone apex to crown (also known as cone center to crown) is not usually given on bevel gear detail drawings, because the location in space is difficult to measure.

XXV CROWN TO BACK

Crown to back is required data on bevel gears only. The distance crown to back is usually given as a reference dimension. If the crown is rounded, this dimension is not directly measurable since the crown point becomes a point in space.

XXVI PITCH CONE APEX TO BACK

Pitch cone apex to back is required on bevel gears only. Pitch cone apex to back (also known as cone center to back) is usually shown to establish the location of the teeth relative to the gear blank.

XXVII THICKNESS OF BLANK

Thickness of blank is required data on bevel gears only.

$$\begin{aligned} \text{Blank Thickness} &= F \cos \phi + \text{Crown to Back} \\ \text{where } F &= \text{Face Width} \\ \phi &= \text{Face Angle} \end{aligned}$$

XXVIII REFERENCE AXIS AND MOUNTING SURFACES

Reference axis and mounting surfaces are required data on bevel gears. In bevel gearing, the bore and the back surface are usually considered as the mounting surfaces. All dimensions should be based on these surfaces.

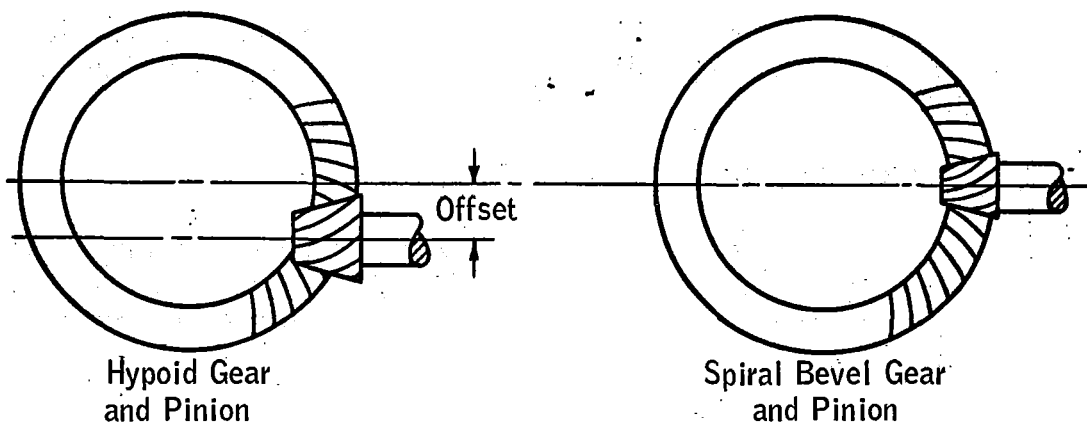
For spur and helical gears, the axis about which the teeth are to be inspected or the surfaces which are to locate the gear in service and about which the teeth are to be inspected should be identified on the drawing.

GEARS

32.3.1 (Contd)

XXIX HYPOID OFFSET

Hypoid offset is required data on hypoid gears only. Hypoid offset is designated as being above or below center. To determine whether offset is above or below center, it is customary to look at the face of the gear member with the pinion to the right.



XXX CROWN TO CROSSING POINT

Crown to crossing point is optional on hypoid gears only. Crown to crossing point is the distance from the crown of the pinion to the point at which the pinion axis crosses the gear axis.

XXXI ADDENDUM

Addendum is optional data, helpful but not essential on drawing. Bevel gear pairs are usually made short and long addendum (except meter pairs) to provide the best balance of strength and contact ratio and to avoid conditions of undercut.

XXXII CIRCULAR PITCH

Circular pitch is optional data, helpful but not essential on drawing.

$$\text{Circular Pitch} = \frac{\pi}{\text{Diametral Pitch}}$$



GEARS

32.3.1 (Contd)

XXXIII CHORDAL ADDENDUM

When gear teeth are measured by a tooth vernier, the chordal addendum is required data.

XXXIV TIP RADIUS

The tip of the gear tooth may be given a radius or chamfer to prevent gouging with the mating tooth and to help prevent the active profile of the tooth from damage during handling.

XXXV END RADIUS

The ends of heavily loaded gears are given an end radius or chamfer to avoid stress concentrations on the teeth. On lightly loaded gears, the ends are sometimes given a radius or chamfer to eliminate burrs and to protect the active profile from damage.

XXXVI ROOT FILLET RADIUS

The root of the teeth should be given as large a radius as practical to reduce stress concentrations at this point.

XXXVII FORM DIAMETER

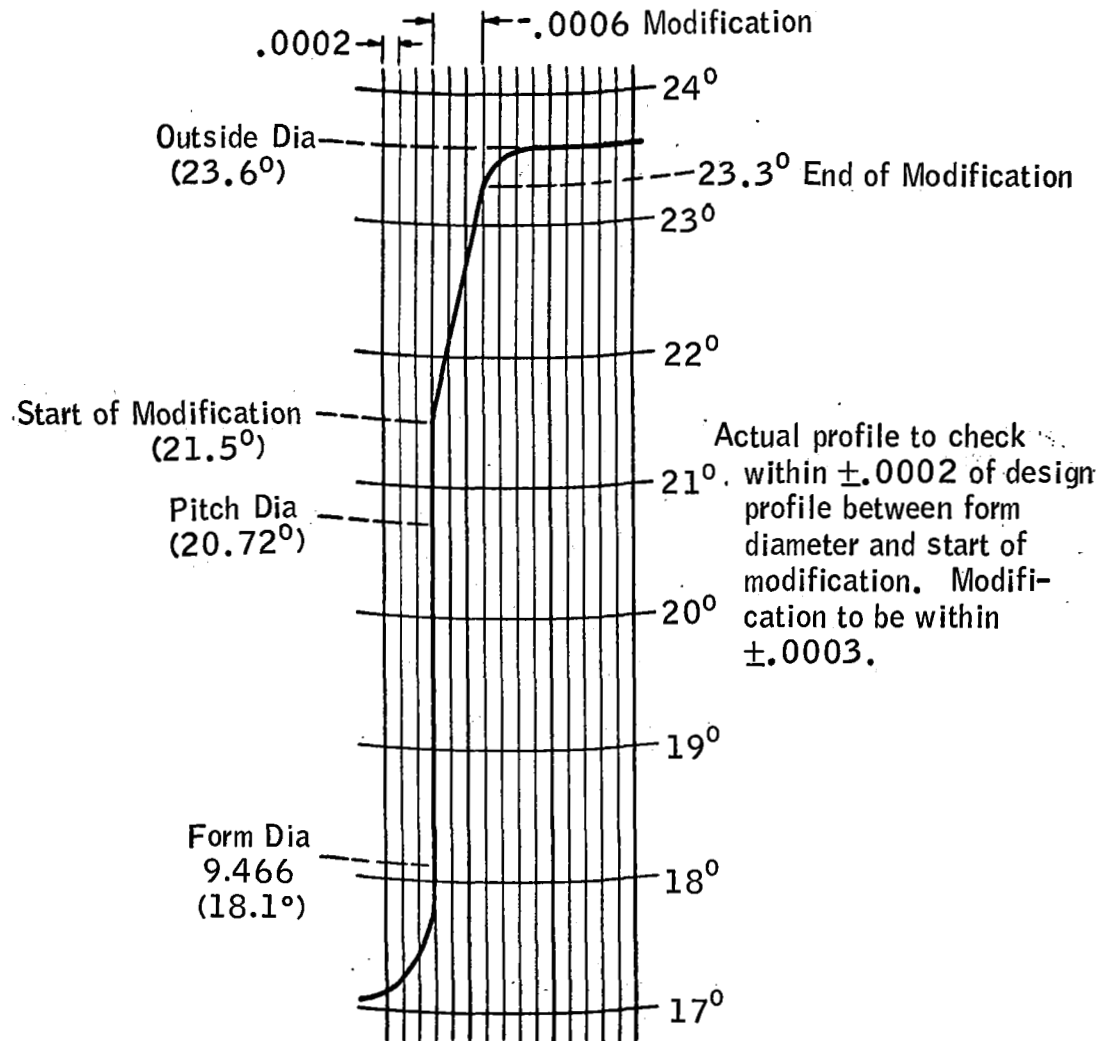
The form diameter is that diameter which represents the design limit of involute action.

XXXVIII PROFILE CHART

When a gear tooth profile is to be inspected on an involute checker, it is desirable to show by means of a chart on the drawing, the allowable deviations from a true involute.

GEARS

32.3.1 (Contd)



XXXIX DIAMETER OVER PINS

Two pins (or balls) of a given size are placed in tooth spaces as nearly 180 degrees apart as possible, and the diameter over these pins is measured. This is a more accurate method of measuring gear tooth thickness than the method using tooth verniers.

XL MOUNTING DISTANCE

Mounting distance is required data on bevel gears only. Mounting distance is the value usually shown in the view of the mounting drawing to show the distance from a shaft axis to a surface in the mounting that provides the axial location of the mating bevel gear. In some cases, the mounting distance is also shown on the detail drawing of the gear.

GEARS

32.3.1 (Contd)

XL I CIRCULAR TOOTH THICKNESS

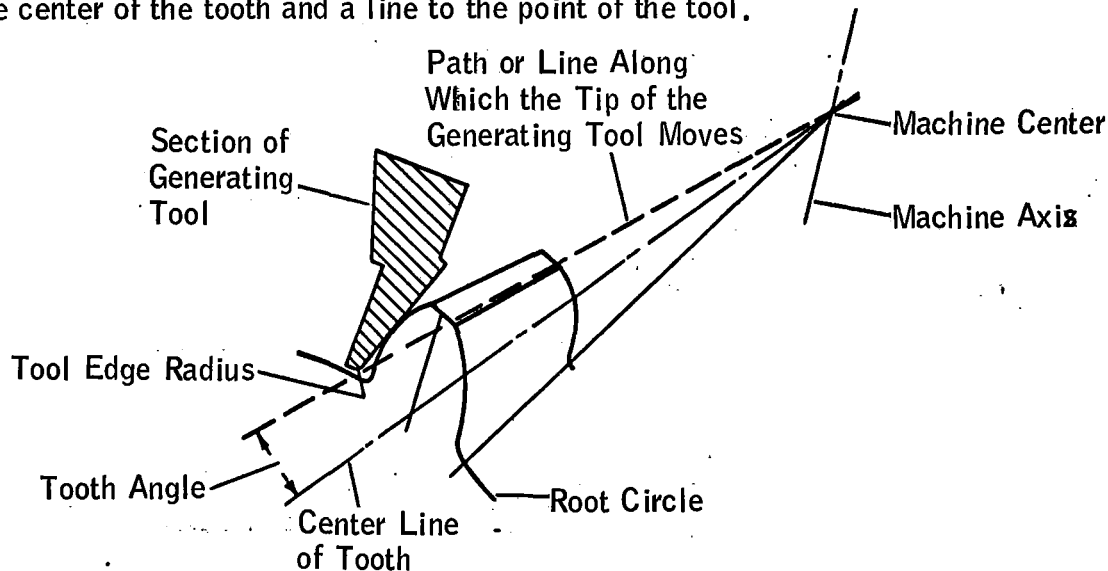
Circular tooth thickness is required data on bevel gears only. See Note 6.

XLII CHORDAL TOOTH THICKNESS

Chordal tooth thickness is required data on bevel gears only. See Note 6.

XLIII TOOTH ANGLE

Tooth angle is required data on bevel gears only. The tooth angle, a machine setting, is defined as the angle at the machine center between a line through the center of the tooth and a line to the point of the tool.

**XLIV LIMIT POINT WIDTH**

Limit point width is required data on bevel gears only. The limit point width represents the largest straight cutting tool that can pass through the tooth space at the small end of the teeth.

XLV TOOL ADVANCE

Tool advance is required data on bevel gears only. Tool advance is an arbitrary increase in whole depth. It is obtained by feeding the cutting tool into the blank a small amount deeper than indicated by the calculated value of whole depth of tooth.

GEARS

32.3.1 (Contd)

XLVI FACE CONTACT RATIO

Face contact ratio is required data on bevel gears only. Face contact ratio is a measure of the average number of teeth in contact. It is used in spiral bevel gearing and hypoid gearing and is an engineering value.

XLVII CORNER ROUND

To avoid injury when handling bevel gear blanks, it is customary to round the corner between the face and the back cones.

32.4 BACKLASH

The backlash in a gear train is introduced to allow for gear tooth errors, runout, and lubricating films on teeth, and for changes due to the effects of temperature. The amount of backlash that should exist in a gear train will depend upon its function and the accuracy of its components. In general, backlash is introduced by cutting the teeth thinner than standard, although, in some designs, it is introduced at assembly by varying the center distance of the shafts on which the gears are mounted. The following table shows the average amount of backlash that may be designed into gear meshes for ordinary applications.

RECOMMENDED BACKLASH FOR POWER GEARING

DIAMETRAL PITCH	BACKLASH
3	.015
4	.012
6	.010
8	.008
10	.006
12	.005
20	.003
32	.002



SPRINGS

33.1 GENERAL

The use of MIL-STD-29, Springs, Mechanical; Drawing Requirements For, is mandatory for drawing, dimensioning, and specifying spring data on detail drawings. Appendix A of MIL-STD-29 which contains material, design, and manufacturing data, is an excellent guide to the engineer or designer for spring design. The use of Appendix A is not mandatory.

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